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ENGLAND AND WALES.

THE

GEOLOGY

OF

SOUTH-WESTERN NORFOLK

AND OF

NORTHERN CAMBRIDGESHIRE.

(EXPLANATION OF SHEET 65.)

BY

W. WHITAKER, B.A., F.R.S., F.G.S., Assoc. Inst. C.E.,
(Editor,)

S. B. J. SKERTCHLY, F.G.S.,

AND

A. J. JUKES-BROWNE, B.A., F.G.S.

(*Partly from Notes by other Officers of the Survey.*)

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PREFACE.

The district represented in Sheet 65 of the Geological Survey and described in the following Memoir, embraces the northern part of Cambridgeshire and the south-western portion of the county of Norfolk. It consists of two distinct areas, differing from each other in topography and in geology. The western and rather larger tract belongs to the flat level region of the Fenland, while the eastern district undulates in low hills and ridges, consisting of Cretaceous rocks, with for the most part a capping of boulder-clay, brown sand, or other superficial deposit.

The western area was chiefly surveyed by Mr. Skertchly, and was described by him in the General Memoir on the Fenland, published in 1877. All matter in that work which refers to the Geology of Sheet 65 has been made use of in the present Memoir, in the form and arrangement that appeared most suitable.

The more varied eastern tract was mapped by Messrs. Whitaker, Woodward, Cameron, Bennett, Skertchly, Hawkins, Reid and Barrow, the portion of ground surveyed by each officer being approximately shown by their notes of local details in the following chapters. The lists of fossils have been revised by Messrs. Sharman and Newton.

The division between the Lower and Middle Chalk was traced at a subsequent time by Mr. Jukes-Browne, and on the north by Mr. Whitaker, both of whom had the advantage of the company of Mr. W. Hill and of his wide acquaintance with the Chalk. Mr. Jukes-Browne has contributed most of the material descriptive of the Upper Cretaceous formations.

The work of the three officers whose names appear on the title-page, forms the chief portion of this Memoir, but the notes of the others whose names have just been mentioned have likewise been used, especially those of Messrs. Woodward, Hawkins, and Reid. The preparation of the work was entrusted to Mr. Whitaker who has arranged and edited it, most of the field-work east of the Ouse having been carried on under his supervision. He has likewise contributed the accounts here given of the literature of the various deposits where the work of previous observers is fully acknowledged.

Among the features of geological interest in the region described in the following chapters, reference may be made to two deposits

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of marine Drift, those of the Nar clay and the March gravel; likewise to the occurrence of channels filled with glacial Drift and extending to a great length, partly even below sea-level; and to the presence of esker-like masses of gravel in the north part of the district. The phosphatic deposit in the Lower Greensand is perhaps the most notable geological feature in the southern part of the ground. In this southern tract also many stone implements have been found in the Drift.

In connection with the occurrence of these relics of early man, we have to thank Sir John Evans for his continued liberality in allowing the use of many wood-cuts from his well-known book. The Council of the Geological Society has also been so good as to permit the reproduction of some illustrations from the Society's *Quarterly Journal*.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
15th September, 1893.

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CHAPTER I. INTRODUCTORY.

Area.

The area represented in Sheet 65 of the Geological Survey Map, and now to be described, is about 820 square miles in extent. It comprises parts of four counties, as follows: the northern part of *Cambridgeshire* (except for the neighbourhood of Whittlesey, in Sheet 64), with the towns of March and Wisbech and the large villages of Chatteris and Littleport; the south-western part of *Norfolk*, with the towns of Downham Market, Lynn, Stoke Ferry and Swaffham; the south-eastern end of the *Lincolnshire* Fenland; a small part of the *Huntingdonshire* Fenland; and a small strip of the north-western part of *Suffolk*, with the border town of Brandon.

More than half of this tract, on the west, belongs to the Fenland, and has therefore been already described in the Memoir thereon, together with some of the border; but the parts of that Memoir which refer to the geology of our district are now reproduced, with some additions and with such alterations as the new arrangement made needful. For an account of the history of the Fenland, of its rivers and drainage, of its inundations and of its meteorology, the reader is referred to the older Memoir.*

Although the district includes some of the highest parts of the large county of Norfolk, yet nowhere is a height of 300 feet above the sea reached.

Rivers.

The chief river is the *Ouse*, which crosses the district from south to north, from just above Littleport to just below Lynn, along a canalized and sometimes a purely artificial channel, and it is tidal for half of this course, up to Denver Sluice, where the tidal action is artificially stopped; naturally the whole would be tidal. The Ouse is an important river, draining a very large tract of land, and within our boundaries it receives the following streams on its right, or easterly, side:—

1. The *Little Ouse*, which enters the district at the south-eastern corner, flows westward for several miles and then, turning north-westward, joins the main river above Southrey. On its way from Thetford (just beyond our boundary) to the Fens, with the exception of a trifling brooklet from Weeting, the Little Ouse receives no tributary, a fair illustration of the dryness of a Chalk-country.

2. The *Wissey* or *Stoke River*, a Chalk-stream, supplemented by some Drift-drainage, two branches of which enter our district on the east, at Little Cressingham and North Pickenham, joining at Hilborough and then flowing southward for a few miles to

* The Geology of the Fenland. By S. B. J. Skertchly, pp. xvi., 335; 24 plates. 1877.

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below Langford. Here a short tributary from Stanford, on the east, imposes its westerly course on the stream, and two miles further down another short tributary, also on the left side, from West Tofts, does the like, giving the river a slight northerly turn. This north-westerly course it holds for about 5 miles. Then three tributaries join, in about a mile, on the right or northern side: first the short streamlet from N.E. of Fouldon, then the brook from east of Cockley Cley, and then the combined brooks from Beechamwell and Fincham; and the result is that from Stoke Ferry the Wissey bends southward, but for less than two miles, when the little stream from Methwold joins on the left side, and gives the river its own westerly course, which it keeps across the Fen to the Ouse, west of Hilgay.

3. The *Nar* or *Setchy* enters the district on the east at East Lexham and flows irregularly westward, without tributaries, through the Chalk-tract, but beyond it receiving, on the right, the streams that rise from the basal part of the Chalk at East Walton and at Gaytonthorpe. On reaching the Fenland the Nar, which is canalized as far up as Narborough, turns northward, and, gradually nearing the Ouse, joins the latter at the southern side of Lynn, together with the stream in the Middleton Valley, which rises at the base of the Chalk at Gayton.

4. On the northern side of Lynn the Ouse receives the stream that rises in the Chalk-springs of Grimston.

The other drainage-system of the tract to be described is that of the *Nene*, which river flows across the Fenland from Eastrea, on the west, to Wisbech, in an artificial channel, and then turns northward across Marshland to Sutton Bridge, being tidal throughout.

The changes that have been brought about in the rivers of the Fenland have been described in the Fenland Memoir.

Geological Formations.

The geological divisions shown on the Geological Survey Map are given in the right-hand column of the following table:—

Recent (Alluvial Deposits)		Alluvium (generally). Alluvium of the Fen Meres. Peat. Fen Silt.
Post-Glacial Drift		Marine Gravel (March, &c.). Loam (or Brickearth). Marl. River Gravel. Marine Clay and Loam (Nar Valley).
Glacial Drift		Gravel and Sand, and Eskers. Boulder Clay. Brickearth and Gravel.
Cretaceous	Chalk	Middle and Upper Chalk. Lower Chalk. Chalk Marl.
		Gault (partly divided, to the north). Lower Greensand, with a middle Clay-division locally, to the north.
Jurassic		Kimeridge Clay. Oxford Clay.

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The *Oxford Clay* comes to the surface only in the south-western corner of the district, and then but slightly, at Ramsey. There is little doubt, however, of its ranging underground beneath the whole of the Fenland, for it has been found in wells at March and at Lynn (see pp. 154, 158) and it may extend far to the east.

Doubtlessly *Corallian Beds* are represented by clays, but they are not distinguished on the map.

The *Kimeridge Clay* crops out from the Fens at various parts, round March, Chatteris and Littleport, on the west and north, and from Southrey to near Lynn, on the east and north, and it is the basal bed of the greater part of the Fens, except where the Oxford Clay rises up from beneath, on the west, and where newer beds come on above, on the south-east.

The *Lower Greensand* and the *Gault* occur at the surface in Norfolk only, where they form a fairly broad, but in great part Drift-covered, tract between the Chalk and the Kimeridge Clay. In their underground course, however, though we have every reason to feel confident that the Gault, though thin and narrow at its outcrop, not only extends far away, to the east and to the south, but also gradually thickens; of the extent of the Lower Greensand, thicker though it be at the surface, we are in much doubt: probably, however, it reaches to our present eastern boundary.

The *Chalk* forms, speaking roughly, the eastern third of the district (including, with Drift-cappings, all the highest ground), whence it extends far and wide beyond our bounds.

The *Glacial Drift*, chiefly represented by Boulder Clay, occurs not only on the high lands of the Chalk and on the hill-tops of the Lower Greensand; but also often sweeps down the flanks of the valleys to their bottoms, and sometimes spreads under the Fens, to some depth. In fact this set of deposits rests very irregularly on those that have been noticed above, except that we have no evidence of it on Oxford Clay, in our area. Between the Chalk and the Drift there is a vast geologic gap, wholly unrepresented by deposits in our district.

The *Post-Glacial Drifts*, on the other hand, do not occur on the higher grounds; but are confined to more or less narrow strips or patches along the bottoms and flanks of the valleys, or as cappings to some of the low islands of the Fens. They consist chiefly of old River Gravel, the other beds being more local.

The *Alluvial Deposits* form the whole of the wide Fenland flat and the narrow marshes along the streams of the eastern tract of higher ground. Though forming the surface therefore of about three quarters of the district, these deposits are of no great thickness, and often indeed very thin.

Shape of the Ground.

The features of the tract represented in Sheet 65 of the Geological Survey Map are simple. We have on the west the low-lying flat of the Fenland, without break in its northern part,

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and on the south but slightly relieved by the various low islands of Drift and Kimeridge Clay that rise out of it. On the east this flat reaches up to the gently-rising hills, which are at first of Chalk, on the south, but northward, as the land projects out into the Fenland-plain, of beds below the Chalk, chiefly Lower Greensand. In rear of these latter the Chalk comes on with a gentle escarpment, not like the marked feature so generally seen, but a long gentle slope, reaching to no great height. The reason of the absence of the usually well-marked feature in the Chalk escarpment is clearly that the whole tract east of the Fens has once been covered by Glacial Drift, during the deposition of which the chief prominences were smoothed down. .

One notable point is the absence of a master-valley, the chief rivers, the Ouse and the Nene, having their course through the Fens. Technically, however, the range .of hills from Downham Market to Lynn is one side of the valley of the Ouse; but the usual idea of a valley needs two opposing slopes, and in this case the western slope has been utterly swept away. The lesser valleys of the Little Ouse, of the Wissey and of the Nar, are not very strongly marked; but they serve to divide the land into blocks, from south to north, being more or less at right angles to the general course of the main stream.

In the north-eastern part of the district a remarkable, though small, feature is sometimes made by Drift gravel, which takes the form of esker-ridges for a short distance. The western part of Norfolk is the only tract in southern England in which such an occurrence has been noticed, though eskers are not uncommon in more northern parts.

Low therefore though our district is, it is not without interest, for, with its bordering land westward, north-westward and south-westward, it gives us our best example of a perfect plain, mostly below the level of high water, and formed by the even deposition of alluvial beds, not by the planing down of erosive actions; though of course the latter must have preceded the former.

Note on the Recent Fauna and Flora of Brandon.

The following remarks, by Mr. Skertchly, are of interest as connecting past conditions with the local existence of some forms of life.

"The native fauna and flora of the neighbourhood of Brandon, is rich and peculiar, as might have been expected, and, in one point, has an interesting bearing upon Post-Tertiary geology. The existence of a colony of maritime species around Brandon was first pointed out by Mr. F. Barrett, who gave a list of maritime insects that he had captured. Prof. Newton, of Cambridge, had however previously remarked that the Ringed Dottrell, a bird only known to breed on the coast elsewhere, nests regularly on the Warrens in this neighbourhood."

"Of the maritime species that have been found by the above-mentioned observers, Mr. A. B. Farm, Mr. A. Grugeon and

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myself, 16 are Lepidoptera, 1 Coleoptera and 4 Plants, and the list is doubtlessly capable of extension."

"The geological interest centres in the fact that we have here a colony of maritime species that cannot have been introduced, but which are the relics of a once wide-spread maritime fauna and flora. The Ringed Dottrell is especially interesting, for it is a migratory bird, and has therefore abundant opportunities of selecting breeding-places more in accordance with its usual habits: yet from time immemorial the bird has bred upon these Warrens. The inference to be drawn from this strange fact, as pointed out by MR. T. SOUTHWELL, is that these birds are the descendants of ancestors which bred in this neighbourhood when it was really maritime, and that they have inherited the habit of recurring to the original breeding-places. So too with the other species: they form, as it were, a living outlier, attesting the former existence of a state of things long passed away, and standing amidst a new and changed state of things, a relic of the past, uninfluenced by its surroundings."

"This colony then must date back as far as the last period when the sea washed the Brandon highlands. That period was far away in pre-historic times, perhaps not long after the close of the Glacial Epoch. The most recent date at which the sea could have reached here was before the formation of the Fenland peat, which peat I have shown is very old, dating back many thousands of years." [Fenland Memoir]

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CHAPTER 2. JURASSIC BEDS.

Oxford, Corallian, and Kimeridge Clays.

General Remarks.

So very little of the Oxford Clay has been seen in the district, as already noticed (p. 3), that it will be better to treat it with the overlying Kimeridge Clay, and the following account of these beds (to the middle of p. 7) is contributed by Mr. H. B. Woodward, who visited the district some years after the Survey was made.

The Oxford and Kimeridge Clays form the foundation of the greater part of the Fenland in the district now described, but the Oxford Clay appears at the surface in the neighbourhood of Ramsey only.

The underground boundary between the Oxford and Kimeridge Clays is necessarily conjectural. We have no evidence of Corallian rock-beds, either at the surface or from borings; but it may be reasonably inferred that Corallian Beds are represented, as in Lincolnshire and in the country to the south, by clays equivalent to the Ampthill Clay, and perhaps also by occasional rock-bands.* This inference is supported by observed facts.

At March the occurrence of *Ostrea deltoidea* points to the presence of the lower part of the Kimeridge Clay, and Mr. Skertchly notes the occurrence of Oxford Clay fossils in another section there. Hence it is probable that the Kimeridge Clay that appears at the surface in the islands of March and Chatteris represents pretty nearly the western border of the formation, and it is also likely that these outcrops belong to outliers, surrounded by Corallian and Oxford Clays, beneath the Alluvium. The section of the March boring (p. 154) is not clear as to the presence of Corallian clay, but is interesting in showing the absence of Corallian rock-beds. The equivalent of the Corallian probably comes in the clay there classed as Kimeridge.

Prof. Hughes speaks of Kimeridge Clay with a band of limestone at Littleport.† The like band at Knapwell (N.W. of Cambridge) is however quite at the base of the Kimeridge Clay, probably in the Ampthill Clay.

Dr. Fitton has recorded the occurrence of *Ostrea deltoidea* at Southrey,‡ and this fossil indicates the lower Kimeridge Clay. He also notes *Ammonites Lamberti* (an Oxford Clay fossil) from the same place; but this may have come from Boulder Clay,

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* See T. Roberts, *Quart. Journ. Geol. Soc.*, vol. xlv. p. 545 (1889), and "The Jurassic Rocks of the Neighbourhood of Cambridge." 8°. 1892. See also Memoirs of the Geological Survey. England and Wales. The Geology of Parts of Cambridgeshire and of Suffolk, pp. 6–8. (1891.)

† *Proc. Geol. Assoc.*, vol. viii., no. 7, p. 401. (1884.)

‡ *Trans. Geol. Soc.*, ser. 2, vol. iv., pt. ii., p. 316. (1836.)

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which exists on the island. [So too may the *Ostrea;* for one would hardly expect the lower part of the clay here, close below the Lower Greensand. W. W.] The occurrence of bituminous shale at Southrey is mentioned by C. B. ROSE,* and this is suggestive of the presence of the higher part of the Kimeridge Clay.

MR. ROSE also records *Ammonites decipiens* from Denver Sluice, and the same species, with *A. excavatus* and other fossils, from the deep well at Lynn (see p. 158). These last were from the lower beds of the clay, so that, as ROSE suggests, the higher beds at Lynn (beneath the Drift) are Kimeridge Clay.† It is of course hazardous to base conclusions on species identified so long ago as 1835; but it is noteworthy that nearly all the fossils recorded from the Lynn boring are among those noted by MR. T. ROBERTS from the Corallian clays of Lincolnshire.‡

The evidence therefore tends to show that a great part of the Fenland (around Wisbech, etc.) is based directly on Oxford Clay, and that a band of Corallian clay separates this from the overlying Kimeridge Clay to the east.

In the eastern part of the district the Kimeridge Clay crops out from below the Lower Greensand at Hilgay (forming the surface of the greater part of the island, to Southrey), and then along the eastern border of the Fens from Fordham to Watlington, and again from the south of North Runcton to Hardwick, S.E. of Lynn. Along these narrow tracts, however, between Fordham and Lynn, the clay is for the most part capped by River Gravel or Boulder Clay.

Northward, beyond Hardwick, the Kimeridge Clay sinks below the level of the Fens, and is not seen at the surface, except just beyond our border, where it rises again for a short distance between North and South Wootton, and there is mostly covered by gravel.

Details.

Two brickyards at Forty-foot Bridge are noticed by PROF. JUDD, who says:—"In one of these, a band of hard rock, 8 or 10 inches in thickness, is found at a depth of 15 feet," and he adds that the following fossils occur: *Ammonites Lamberti* (many varieties and in great abundance), *Belemnites hastatus* (very abundant), *Belemnites puzosianus* (rare) and *Gryphæa dilatata* (moderately abundant).§ These species indicate upper beds of Oxford Clay, though not the highest.

A like assemblage of fossils is also recorded from a brickyard at Eastrea,‖ so that the gravel-covered tract of Coates, on the western side of Eastrea Fen, and the small tract north of Wryde Station, are probably based on Oxford Clay.

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* *Phil. Mag.*, ser. 3, vol. vii. pp. 174, 175. (1835.)

† *Ibid.*, pp. 173, 174. The Lynn fossils are also referred to by FITTON. *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 316.

‡ *Quart. Journ. Geol. Soc.*, vol. xlv. p. 556, and "The Jurassic Rocks of the Neighbourhood of Cambridge."

§ Memoirs of the Geological Survey. England and Wales. The Geology of Rutland, etc., 1875, p. 237.

‖ *Ibid.*, p. 238.

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The section at Pape's brickyard, White Lion Lane, March, has been thus recorded by Mr. Skertchly:—

		Feet.
Gravel, rudely bedded and in some places false-bedded; much mixed with clay and sand; composed largely of pebbles of chalk and of Oolite limestone, with small flints, and pebbles of quartz, Coal Measure sandstone, &c.; very full of broken and whole marine shells		6
Yellow clay, with stones and striated pebbles of chalk and Lias limestone (Boulder clay)		4 to 5
Kimeridge Clay, etc.	Yellow clay, with *Ostrea deltoidea*	7
	Layer of clunch stones (septaria)	½
	Blue clay	14

The beds are classed as Kimeridge Clay because most of the fossils are of that age, but Oxford Clay (? Corallian) fossils are also found.

From the same authority we have the following sections at Hutchinson's brickyard, close to the Railway Station, where the eastern side of the pit showed the following beds:—

Whitish-grey silt or warp, bedded, with 5 species of marine shells; 12 feet. The ordinary Fen Silt, the gravel being absent.

Kimeridge Clay, to 40 feet.

On the western side of the pit the section was:—

Gravel (almost removed when the note was made), full of marine shells, in pockets, formerly 6 to 20 feet thick.

Dark blue Boulder Clay, with many striated chalk-pebbles. 6 feet.

Dark blue Kimeridge Clay full of *Ostrea deltoidea* in the top 4 feet, to 40 feet.

The brickyard a quarter of a mile S.W. of Fordham Station showed dark clay, with shells.

The cutting on the Stoke Ferry Railway just S.E. of Denver Station, which reaches only a depth of about 4½ feet, showed Kimeridge Clay beneath a gravelly soil.

Mr. Skertchly has also recorded the section at the brickyard S.E. of the Railway Station, Downham Market, as follows:—

		Ft.	In.
Sandy soil		2	0
Ferruginous sandy bed, cemented into soft ironstone where long exposed		0 to	10
Sand and fine gravel [local; at the southern end]		10 in. to	1 8
Kimeridge Clay	Dark blue clay [not so deep in 1880]	30	0
	Stone floor (septaria)	1	8
	Dark blue clay.		

Of this pit Mr. Woodward remarks (1890) that "saurian bones are not uncommon, and various shells are poorly preserved in the papery shales. The beds belong to the upper part of the formation both here and at Watlington."

At the Gasworks a little to the east (on the western side of the railway), I was told in 1880 that beneath 3 feet of loam (? wash from the sand higher up), clay, with hard layers, cement-stone and shells, was dug into to the depth of 13 feet. A heap of the shaly clay, lying by the roadside, was very full of shells.

At the brickyard about two thirds of a mile S.S.E. of Watlington church (to be distinguished from Wallington, a little southward, S.W. of which place too the clay has been worked) the section was mostly inaccessible, in November 1883, from the water. Irregular sand and gravel, with some lumps of clay, was seen resting very irregularly on clay, which sometimes came up in peaks to the surface of the ground, except for soil. The top part of the clay was of lighter bluish-grey than the rest, which was of the usual dark grey. There were fossils on the clay-heaps, and amongst them pieces of reptilian bones.

At West Winch a brickyard half a mile south of the church showed messy gravel and sand over the clay.

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In April 1886 Mr. F. Valentine wrote to me that he had just seen a new section, along the Nar Valley Drainage-works at West Winch Common, in which clay with cement-stones (presumably Kimeridge) occurred about 9 feet down.

The clay was again seen, beneath the gravel, in the railway-cutting at the high road about 1¼ miles northward of West Winch.

Rose says "This clay has also been opened at Gaywood near Lynn, in sinking a well fifty feet in depth: the first eighteen feet were sand, succeeded by fourteen inches of blue clay; then followed a laminated clay containing *Septaria*, which continued to the depth sunk."*

The Fodderstone Gap brickyard is of interest from a large mass of Kimeridge Clay being worked, which is in such a position as to show that it must be a boulder (see p. 63).

Fossils.

The following list has been taken chiefly from the Fenland Memoir (p. 317), but partly from Fitton (*Trans. Geol. Soc.*, ser. 2, vol. iv. p. 316), and from Rose (*Phil. Mag.*, 1835), with some additions and corrections. The whole has been revised by Mr. G. Sharman and Mr. E. T. Newton.

D = Downham Market (brickyard). L = Lynn (deep boring). M = March. S = Southrey.

REPTILIA.

Plesiosaurus (centra)	—	—	M	
Pliosaurus (centra and femur)	—	—	M	
Saurian teeth and bones	—	—	—	S

PISCES.

Asteracanthus ornatissimus, *Ag.*	D			
Pycnodus	D			
Strobilodus (Thlattodus) suchoides, *Owen*	D			

MOLLUSCA.

Cephalopoda.

Ammonites Achilles, *D'Orb.*	—	—	M	
„ athletus, *Phill.*	—	—	M	
„ Bakeriæ, *Sow.*	—	—	M	
„ biplex, *Sow.*	D	—	M	
„ calisto, *D'Orb.*	—	—	M	
„ calloviensis, *Sow.*	—	L		
„ cordatus, *Sow.*	—	—	M (boring).	
„ „ var. excavatus, *Sow.*	—	L		
„ decipiens, *Sow.*	—	L		
„ Eumelus, *D'Orb.*	—	—	M	
„ Eupalus, *Sow.*	—	—	M	
„ Koenigi, *Sow.*	—	—	M	
„ Lamberti, *Sow.*	—	—	M	S?
„ Mariæ (?), *D'Orb.*	—	—	M	
„ mutabilis, *Sow.*	—	—	M	
„ (Trigonellites)	—	—	M	S
Belemnites abbreviatus, *Miller*	—	L		
„ hastatus, *Montf.*	—	—	M	

Gasteropoda.

Cerithium	—	—	M	
Pleurotomaria reticulata, *Sow.*	—	—	M	
Vermetus	—	—	—	S

* *Phil. Mag.*, ser. 3, vol. vii. p. 175. (1835.)

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Lamellibranchiata.

Arca æmula, *Phill.*	—	—	M	
Astarte aliena, *Phill.*	—	—	M	
„ carinata, *Phill.*	—	—	M	
„ ovata, *Smith*	—	—	M	
Avicula inæquivalvis, *Sow.*	—	—	M	
Gryphæa dilatata, *Sow.* (also given as Ostrea bullata)	—	L	M	
	—	—	M	
Hinnites velatus, *Goldf.*	D			
Lucina minuscula, *Blake*	D	L	M	S
Ostrea deltoidea, *Sow.*	—	L		
Thracia (Mya) depressa, *Sow.*				

Brachiopod.

	—	—	M
Rhynchonella inconstans, *Sow.*			

ANNELIDA.

	—	—	M
Serpula tetragona, *Sow.*	—	L	
„ tricarinata, *Sow.*	—	—	M
„ variabilis, *Sow.*			
		L	
Echinus spine			

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CHAPTER 3. CRETACEOUS BEDS.

Lower Greensand.

General Remarks.

Though of no great thickness in our district, where perhaps it does not reach to 150 feet from top to bottom, the Lower Greensand nevertheless has a fairly broad outcrop, from Denver and West Dereham on the south to Gaywood and Grimston on the north, sometimes to the extent of about five miles. It is much hidden however under Boulder Clay, Gravel, Brickearth and Alluvium, the last alone wholly covering it along the bottom of the Nar Valley.

On the south the formation is hidden under the Fens, and the most southerly places where it is seen are the two small patches at Southrey, with another near Hilgay. It crops out from the Fen of the Wissey at Hilgay and, on the other side of that stream, at Fordham; but whether the two patches join underneath the Fen or not is doubtful, and the like is the case with the Fordham patch and the main outcrop to the north, Kimeridge Clay being probably cut into by the deep channel of Boulder Clay north of Fordham.

The Lower Greensand is essentially a sand, commonly ferruginous and sometimes hardened into an iron-sandstone (carstone). On the north however there are some traces of a clayey member, which, further north beyond our district, is clearly continuous and divides the sandy mass into two.

Small scattered phosphatic nodules are of common occurrence, in the lower part at all events; but not in quantity enough for working, except at West Dereham, at the top of the formation. From the fact that these are worked together with the nodules at the base of the overlying Gault clay the accounts of the sections will fall under two heads, depending on the distinction of the older bed.

Before taking up the detailed description of sections it will be of interest to notice the literature.

The works that treat of the Lower Greensand of Norfolk are few, and the first account of it in our district, save for the slightest notice of its occurrence, is by the old Norfolk geologist C. B. Rose, who, in his "Sketch of the Geology of West Norfolk," described the formation under the name Inferior Greensand and gave sections at various places.* Fitton's great paper† published the following year, and so full of information on other parts, contains only four paragraphs on our district, and these almost wholly on the authority of Rose's "Sketch."

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* *Phil. Mag.*, ser. 3, vol. vii. pp. 175–179. (1835.)
† *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 313.

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The next contribution too, as far as our district is concerned, was from the same author, in a paper "On the Cretaceous Group in Norfolk," wherein he says:—"This deposit occurs in three forms": loose light-coloured sand, often false-bedded; sandstone, "provincially called Carstone"; and "a breccia, composed of small siliceous pebbles and angular fragments cemented together by ferruginous sand, and traversed by very thin seams of carbonate of lime";* but this last, I think, occurs only to the north (Sheet 69).

It was not, however, until several years later that the occurrence of definite divisions in the Lower Greensand of Norfolk was seen, and the credit of this, the most important piece of work on the formation in the county, belongs to MR. J. J. H. TEALL, whose divisions are the same as those shown on the Geological Survey Map. Though this refers chiefly to the tract to the north (Sheet 69), yet there are traces of the middle clayey member in our district. MR. TEALL was also the first to describe the phosphatic deposits at West Dereham, the fossils of which he thinks show "a close relation between this stratum and the Ammonites mamillatus [mammillaris] zone of Folkestone."†

Eight years later these phosphatic beds were again noticed, somewhat more fully, in the last publication that refers to the Lower Greensand of our district, by MR. W. KEEPING,‡ who says that, instead of the usual abrupt junction, "at Downham Market [West Dereham] there appears to be a perfect passage . . from the sands below to the overlying gault." He goes on to say, "I find, from the fossil evidence, that this bed is totally distinct from all the other worked coprolite beds of the Eastern Counties, and must be kept clearly separated off from them." He revised Mr. Teall's list of the fossils, separating the Gault species (the nodules from the Gault being mixed in the heaps, with those from the sand) and giving the following, to which MR. SHARMAN adds *Pecten cinctus* (?) as Neocomian:—

Ammonites Beudanti, *Brong.*
Aporrhais.
Pleurotomaria.
Solarium.
Cyprina ligeriensis, *D'Orb.* and another sp.
Pecten (Janira) Morrisii, *P.* and *Ren.*
Pecten orbicularis, *Sow.*
Spondylus.

He agrees with Mr. Teall's conclusion that the nodule-bed belongs to the *Ammonites mammillaris zone*, and thinks that it had "better be taken as the basement bed of the gault."

Details, between the Little Ouse and the Nar.

Of the western of the two small patches at Southrey MR. REID notes that "a pit close to the old church gave the following section, in 1883":—

Gravel, of carstone and a few flints; 6 feet.
Bluish loamy sand (Lower Greensand); 5 feet.

* *Proc. Geol. Assoc.*, vol. i., no. 8, pp. 234, 235. (1862.)

† The Potton and Wicken Phosphatic Deposits, 8°, *Cambridge* and *London*, chap. iii. 1875.

‡ The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill, 8°, *Cambridge*, 1883, pp. viii., 10–12, 53–56.

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Mr. P. Bunn is credited with the finding of a bed of phosphatic nodules in clay between West Dereham and Downham,* but these may have been from the Gault rather than from the Lower Greensand; and the section of the workings at the former place was noted by Mr. Jukes-Browne in June of the same year (1874), later by Mr. Teall,† and in December 1876 by Mr. W. Keeping.‡ Unfortunately these observers have not given the precise spots of their sections, the last indeed having wrongly described the place as at (instead of near) Downham Market; and, as the bed has been worked over a large tract, one cannot be certain that the sections noted were all at one place. Mr. Jukes-Browne tells me however that the section he saw was nearly half a mile west of the church, and that Mr. Teall saw the same. In this case it is a different section from the others more precisely recorded.

In 1880 I saw what is probably the most easterly working, on the western side of the road five eighths of a mile S.W. of West Dereham church, where the section open showed patches of gravel resting irregularly on clayey Lower Greensand, though clay (Gault?) was seen close by.

Other works, on the northern side of the road rather more than the same distance W.S.W. from the church, showed Gault over Lower Greensand.

The following general account of the sections has been compiled from the MS. note of Mr. Jukes-Browne and the published descriptions of Mr. Teall and Mr. Keeping.

Surface-soil, with flints. The flints go some depth into the clay beneath, making it difficult to separate the surface deposit from the Gault (Teall).

Gault, to 10 feet.	Light-bluish-grey clay, with *Ammonites interruptus* and *Inoceramus concentricus*.
	Grey clay, mottled white, and clayey sand. Phosphatic nodules common and some large; also phosphatized fossils. Worked for the phosphate. Passes down into the next.
Lower Greensand.	Light-brown or yellowish, sometimes calcareous sand, sometimes hardened by iron-oxide; with black phosphatic nodules and many fossils. This is the coprolite-bed. To over a foot.
	Hard sandstone or carstone, with phosphatic nodules; about half a foot.
	Red white and green sands, with some harder layers; found by a well-boring, to the depth of 20 feet.

Mr. Teall says that "*the nodules are not derived, but are simply portions of the matrix charged with phosphatic matter*. . . . They are of the character of subsequent concretions, and are due to the segregation of phosphatic matter round definite centres. Fossils are rare in the nodules themselves, though they occur abundantly in the rock-matrix." Mr. W. Keeping§ describes them as "large and rounded nodules, but unworn; . . dirty white . . and dark green. . . Their surface is not smooth as with the much eroded derived nodules of other places, but rough . . with projecting grains of quartz,

* Norfolk News, 23 May 1874.

† The Potton and Wicken Phosphatic Deposits, pp. 20–22. (1875.)

‡ The Fossils, etc., of the Neocomian Deposits of Upware, etc., pp. 11, 12. (1883.)

§ *Ibid.*, p. 12.

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etc. . . This is especially the case with the pale forms. . . The dark green nodules are of an older . . . origin, for they are frequently included within the paler ones. . . The fossils . . are principally in the state of internal casts in a dark variety of phosphate."

Mr. Reid says that "on the top of the sandy hill half a mile N.N.E. of Bazil Farm there are many scattered coprolites. Probably the coprolite-bed is nowhere undisturbed on this dip-slope."

Between West Dereham and Fordham I saw sections in the railway-cuttings on either side of the place named Roxham. That to the east is shallow and in sand with a broken-up ferruginous capping. That to the west is small and showed buff and brown clayey sand at the eastern end, whilst elsewhere it is in green sand, with ferruginous masses and phosphatic nodules, and in part clay, the top weathered brown. On the road to the north, about three quarters of a mile eastward of Fordham Station, clayey greensand was seen.

At Denver I saw clayey green sand a quarter of a mile a little E. of S. from the church, and the damp ground to the east is a little suggestive of clayey beds.

Mr. Rose has printed two notes on the sand at Downham Market, but without giving the exact locality. The earlier is that the sand "is covered by two or three feet of thin tabular carstone" and that "six feet from the surface, there is a thin stratum of *fullers' earth* about an inch in thickness, of an ash colour, with ochry specks . . its analysis gives an abundance of iron in its composition, with a very slight trace of carbonate of lime."* The other note says that "*Trigonia alæformis* and *T. clavellata* are met with in a bed of ferruginous sand"†; but these species (of Parkinson) do not occur in the Lower Greensand, and probably the right name is *Trigonia ingens*, that species being recorded from Downham, by Dr. Lycett.

Thinly bedded iron-sandstone occurs a little eastward of the church, and light-coloured sand was dug (1882) on the northern side of the lane less than a quarter of a mile south-eastward from the church; and has been dug just by in the fork of the road.

At a lower level, north-westward of the church there is clayey ground, and at the corner of the lane nearly half a mile N.W. of the church I saw clayey green sand and small phosphatic nodules, turned out from a ditch.

Mr. C. Reid has noted the following sections in the large pit by the eastern side of the high road half a mile and more north-eastward of Downham church :—

At the middle part
Soil; 1½ feet.

Lower Greensand.	Buff sand; 5 feet.	
	Thin flaggy carstone; a foot.	
	Current-bedded white or buff sand; 6 feet.	

At the northern end
Soil; a foot.

Lower Greensand.	Buff current-bedded sand; 10 feet.	
	Carstone and green sand; 2 feet.	
	Sand; 2 feet.	

And at one place a thickness of 3 feet of sandy gravel (of carstone and flint) was seen.

The same observer noted the beds shown in work for the foundations for a new bridge (1881) at the northern end of the avenue to Stow Hall; and about a third of a mile east of Wallington.

Made ground; 2 feet.
Peat; 1½ feet.
Greenish sandy gravel; 1½ feet.
Loamy greensand; a foot.

* *Phil. Mag.*, ser. 3, vol. vii. p. 178 (1835), and (partly) in *Proc. Geol. Assoc.*, vol. i., no. 8, p. 235. (1862.)

† *Geol. Mag.*, vol. iv. p. 31. (1867.)

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It is clear that all the beds but the lowest are deposits of the little stream.

The Lower Greensand is cut into along the left side of the valley of the Nar for some way.

At Tottenhill I saw green sand about two thirds of a mile W.S.W. of the church, and on the western side of the high road nearly a mile south of the church a pit showed gravelly sand over sand.

Mr. C. E. Hawkins has supplied the following notes :—

"At Wormegay there is a section at the bridge over the deep drain, west of the village, showing dark green clayey sand. Over the greater part of the island the sand is covered by Drift; but the former can be traced from the village along the southern border of the island. A pit in the wood on the western side of the churchyard showed sand below Boulder Clay."

"The sand rises to a fair height at Shouldham Warren and forms a marked hill. Sand is dug at the north-eastern corner, by the edge of the fen."

Rose has described a pit here as showing "variegated sands, to the depth of twelve feet, covered by three or four feet of rubbly carstone and ferruginous sand. The varieties of sand here are white and brown, thin veins of the latter running horizontally through the former, and frequently assuming a concentric form."*

Mr. Hawkins notes that "about three quarters of a mile westward of Marham a small spur of Lower Greensand projects, from beneath the Gault, into the fen, forming firm ground."

Details, between the Nar and the Middleton Drain.

North of the Nar marshes the Lower Greensand rises up by Pentney Priory; but the outcrop is interrupted northward and westward by channels of gravel, brickearth and alluvium that divide it into separate patches.

In a pit three quarters of a mile S.W. of Pentney church, through the patch of gravel that runs up to the base of the Gault, a little gravel was seen over the sand, which was dug into to the depth of 15 feet.

Mr. Rose has remarked that "At Bilney [Bilney Lodge ?] . . three varieties are distinguishable—1st, a brown tabular sandstone; 2, a green clay; 3, a brown Carstone in large rhomboidal blocks."†

Over 1¼ miles S.W. of West Bilney church the field west of the lane running north to Bilney Lodge is remarkable for the peculiar crimson-red tint of the soil, especially notable in bright sunshine.

Carstone was seen in two pits, marked on the map, on the eastern side of the lane a little south-westward of Bilney Lodge (the nearer giving a fair section in 1882), and on the northern side of the stream N.E. of the same house. The following section, by Rose, may refer to the more northerly of these, as he describes it as "in a pit adjoining the garden of Bilney Lodge."‡

Soil and loam; 2 to 4 feet.
Rubble-car; 2 feet.
Regular car of very loose texture; 5 feet.
Friable sand, the upper part ferruginous, the lower green, with thin tabular carstone and blocks of the same, also geodes and hollow cylinders of ironstone filled with sand; 4 feet.
Car with thin veins of ironstone containing a little clay; 4 to 6 inches.
Hard carstone, in layers from 9 to 30 inches thick, some separated by very thin layers of sandy clay; also divided vertically into irregular rhomboidal blocks; 6 feet.

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* *Phil. Mag.*, ser. 3, vol. vii. p. 178. (1835.)
† *Geol. Mag.*, vol. iv. p. 31. (1867.)
‡ *Phil. Mag.*, ser. 3, vol. vii. pp. 177, 178. (1835.)

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He adds that "A few hundred yards to the south . . a well has recently been sunk," giving the following section, presumably in great part below that of the pit:—

	Feet.
Ferruginous sand, with geodes and hollow cylinders of ironstone	7
Carstone	8
White sand, with occasional brown veins	7
Green clay	½
Carstone, darker than the beds above	2
Carstone, with 6 or 7 partings of green clay (1 to 2½ inches thick) but not in regular courses	3

In the larger outcrop that reaches from East Winch to West Winch there are some good sections, in describing which we will follow the course of the Nar Valley westward, then turn northward along the main valley, and then eastward up the Middleton Drain Valley.

Carstone was seen by the cross roads at Blackburgh, about 1½ miles S.S.E. of Middleton church, whilst just above northward there is sand, some, beneath gravel, being light-coloured. It was probably to the first site that Rose referred as follows: "At Middleton, to the left of the road leading from East Winch to Setch,* a large quarry is worked for building-stone, called the Blackborough Car-pit . . to the depth of 20 feet, and the stone is highly ferruginous, overlying the loose variegated sand which comes to the surface at the base of the hill towards the west . . the carstone is intersected by innumerable veins of *ironstone* from one eighth to an inch in thickness; they run horizontally and vertically, forming grotesque lines, all tending to a concentric arrangement. . . . The carstone is very friable when first raised, but hardens by exposure and becomes an imperishable building-stone."†

The large carstone-pit three quarters of a mile S.S.E. of Middleton Church was being worked in 1883 at the south-eastern corner only, where the section seen was as follows:—

Crimson-purplish soil, sandy and deep; probably merely weathered carstone and sand.
Rubbly carstone, in small pieces, and sand.
Firmer carstone.

Along the southern face the lowest bed increases, gets more massive westward, and shows joint-surfaces in places. The section indeed becomes of carstone only, the top part rubbly and with sand, at top sometimes weathered to a crimson tint, which occurred only on the outside of the pieces of stone.

At the west, close to Middleton Hithe, there is light-coloured sand beneath the carstone.

The northern face showed carstone, weathered at top to a sort of crimson tint.

Whether the following notice by Dr. Fitton refers to this pit or to some other can hardly be told, as the two distances specified do not agree:—"between 38 miles and 39 miles from Norwich, about half a mile from Middleton, are pits of yellowish and white sand, with ferruginous concretional bands, apparently belonging to the upper member of the Lower Greensand."‡

In an old pit in the northern angle of the roads at Middleton Hithe the sand is in part hardened into stone.

Near here springs are thrown out, about three quarters of a mile southward from the church, whilst further south, by the edge of the marsh, green sand occurs, and at one place (where the little inlet of Alluvium begins, about a mile a little W. of S. from Middleton church) phosphatic nodules were seen.

* Setchy of the map. And there are two such roads.
† *Phil. Mag.* ser. 3, vol. vii. p. 177. (1835).
‡ *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 313. (1836.)

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On the road three quarters of a mile S.W. of the church clayey sand and sandy clay, partly green, were shown, but little above the Kimeridge Clay; and, just north, by the junction with the clay, there is some ferruginous conglomerate with phosphatic nodules.

Phosphatic nodules and ironstone were seen about half a mile south-south-eastward of North Runcton church.

In the small side-valley S.W. of that church a little way above the base of the Lower Greensand there were seen, turned out from a ditch, many large lumps of iron-pyrites, one nearly a foot long. In the stream are others and also small phosphatic nodules, some cemented together by pyrites. There is often green sand hereabouts, and this occurs with phosphatic nodules at the hedge-corner half-a-mile W.S.W. of North Runcton church.

S.E. of West Winch the Lower Greensand is in great part clayey.

Pyrites was again seen in the little valley to the west, and ironstone resting on Kimeridge Clay.

A deep drain down to the little valley, from the pond (marked on the map) by the road about a quarter of a mile N.E. by E. of West Winch church, was clear (in 1883) only in places in the lower part of the field, where it showed chiefly clayey green sand, some iron-sandstone (above the sand) and a few phosphatic nodules. There are other signs of green sand in this little valley, and along the track just east of the drain, and higher than the green sand, there is grey clay and clayey sand, which may represent here the middle or clayey division of the Lower Greensand.

Green sand was again seen by the eastern and by the western sides of the high road, respectively a mile and 1¼ miles N.N.W. of North Runcton church.

About a third of a mile eastward of Hardwick Toll green sand was seen beneath Boulder Clay, and further on, in the corner of a field some way above the marsh, and about half a mile eastward of Hardwick Toll, there are a few nodules, which seem to be phosphatic, with casts of bivalve-shells. These are probably from the base of the Lower Greensand (which formation is shown along the ditch westward) as grey (? Kimeridge) clay occurs in the bottom of the ditches close by.

Green sand and sandstone occur a little over three quarters of a mile N.W. of Middleton church, and the ground a little below the Boulder Clay about half a mile north-westward of the church is springy.

About five eighths of a mile N. of W. from East Winch church, where a copse is marked on the map, is a spring, and a little higher S.E., carstone was worked, as also on the southern side of the high road three eighths of a mile W.S.W. from the church.

On the south of the railway less than a quarter of a mile westward of East Winch Station green sand was seen.

The railway-cutting E.S.E. from East Winch Station, though small, must have been of interest; but it was overgrown in 1883. Near the station, and for some little way on, the ditches show green sand. Farther on is ferruginous sand and grit, with small pebbles of quartz, and partly hardened into stone (the like being seen also in ditches in the neighbouring fields). A little beyond the track across the line whitish marl seems to come on above, and soon reaches down to the bottom; the bottom part being rather sandy, with quartz grains and some phosphates, partly of a pale pinkish-brown tint, and perhaps passing down into the sand: this, taken at first for Chalk Marl is presumably the Gault of the country. But a little further on the so-called Nar Valley Beds (clay and loam) come on, cutting out the beds beneath, and an oyster-bed is shown in the ditch. At the cottage, by the road, there is sand and gravel, presumably over the Nar Beds.

Details, between the Middleton Drain and the Leziate Stream.

It is in this tract that we find clear evidence of the presence of the middle clayey member of the formation; though, as may be seen from some of the foregoing notes, there are facts that lead one to suspect its possible occurrence to the south.

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Just below where the Boulder Clay comes on a little S.E. of Ash Wicken church, there was, in 1883, a section of carstone.

The tramway from Middleton Station up to the sand-pits, northward, shows at first sand, partly ferruginous, partly greenish, capped by a sandy gravelly wash (with a few rather large flints). Further on a little dark grey sandy clay and clayey sand were seen, and some large lumps of iron-pyrites have been thrown out from the sand. Still further there is light-coloured sand, with a hollow filled by sandy stony wash, which latter makes it doubtful whether some of the sand lower down the slope may not be a sort of Drift, though it seemed safer to leave it as Lower Greensand. Then the light-coloured sand runs all the way up to the pit, where some of it is of a pale greenish-grey tint, and other parts get that tint at the surface along the course. The pits were shallow, from the occurrence of water, and in like light-coloured and pale green sand.

In the large, but also shallow, old pit northward, which has been reached by a roadway from the north, the bottom again reaches water and the sides show a few feet of light-coloured sand, with gravelly soil in parts.

Further northward are other shallow old pits, with water.

The Eastern and Midland Railway made a set of cuttings across this sand-tract, some time after the Survey was finished, and it will be convenient to describe all these cuttings together, though thereby somewhat breaking our route round the tract.

The cutting at Mintlyn was overgrown in July 1886. At the south-western end there is sand, partly clayey, and wet at the base; and the like was seen on the other side of the bridge over. Beyond the bridge, north-eastward, there is apparently a line of dampness, that sinks from near the top of the cutting to the level of the rail (which rises), and above this there seems to be dry sand, with a small hollow of sand-capped Boulder Clay at the highest part.

The next cutting, in the wood a little E.N.E., was also mostly overgrown, but all in dry sand.

The next, which begins as the line curves slightly northward, is at first only a shallow scrape in sand; but, further on, runs through a hill of light-coloured sand, ferruginous at top in one part. This ends in the site of the Gayton Road Station, on the south of the high road. Over the broad area cut back here the base is damp, water being only 15 inches down in the well.

Just north of the high road the line runs through another hill. At the top the sand is light-coloured, for a depth of about 8 feet, then it is brown (iron-stained) for from about 8 to 12 feet, the colour ending evenly at top, but irregularly at bottom, and then there is again light-coloured sand, to a depth of 12 feet or more, wet at the base.

On the southern side of the little valley west-south-westward of Mintlyn Church the ground is partly clayey; and a pit more than half a mile westward of the church showed carstone beneath the sandy soil.

Just eastward of Gaywood the middle clayey member of the Lower Greensand is mappable for a short way, along the western and northern slopes, from the Hall to New Spring; except where it is hidden by Boulder Clay.

At the eastern side of the little wood at the latter place there were, in 1886, some shallow cuttings in sand, cemented to an ironstone at the surface (? through water thrown out as springs), and in the clayey beds that occur here in the sand. The ironstone, a sort of bog iron-ore, is vesicular, and has been used in purifying gas.

The kiln seven eighths of a mile W.N.W. of Ash Wicken church is supplied from the same beds. The slightly purplish tint of the clayey bed is perhaps more marked here, and at the part where the base of this bed was seen it was marked by a ferruginous layer. At a later visit, in 1892, the pit had been cut back, giving the following section:—

Sand, with thin layers of iron-sandstone; to 10 feet.
Grey finely-bedded clay, partly ochreous, throwing out much water from the sand above; to over 7 feet.

The clayey beds were also touched in a small pit, near the top of the Common, round the hill northward, and in Bawsey Brickyard (see pp. 64, 65); but both

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here and at the place next to be noted, to the east, they are so thin that they can only be shown on the map by a line, and then for no great way.

At the brickyard about half a mile N.W. of the church, and at a rather lower level, the following section was seen in 1883:—

Lower Greensand.	A little brown sand, partly in pockets or undulations.	
	Grey loam, bedded, but undulated with ferruginous concretions; up to 8 feet.	
	Light-coloured sand.	

At the farm about 1¼ miles W.N.W. of Gayton church the ground is very swampy, and there is some light-bluish-grey clay to be seen which belongs probably to the clayey beds in the Lower Greensand, which are here mappable westward to Leziate, though at last only by a line.

Details, north of the Leziate Stream.

The streams from the Sow's Head and Well Hall Springs are badly marked on the old map. They really join further east than is shown, and consequently, though the Lower Greensand crops out a little below their junction, I was obliged to draw the line of outcrop as above it. This line is here in a tolerably perfect flat.

At the junction, along the stream, there is clay above clayey sand; and at the lane about half a mile S.W. of Grimston church there is green sand just below the Gault.

The swampy flat south of Grimston Common was troublesome. The stream is not rightly marked on the map, and there may be some Drift gravel and sand both here and eastward, in which case there may also be Drift clay or brickearth beneath. This is so doubtful however that it was thought best to leave the tract as Lower Greensand, the clay in which may be the cause of the growth of oaks, etc., eastward of the Common, although there was no evidence to warrant the mapping of that clay.

A pit on the Common, about a third of a mile south of the brickyard (see p. 89), gave the following section, in 1883:—

Lower Greensand	A little sand.	
	Grey clay, weathering brown, and stained red and crimson in the lower part; hardly over a foot.	
	Firm buff sand.	

A small pit, near the hill-top, nearly a quarter of a mile N.E. of Bawsey Spot House showed irregular carstone, with sand, the upper part much reconstructed (with hematitic nodules, phosphatic nodules, some decomposed, one being a piece of a large *Ammonite*, and a few flints).

Nearly a quarter of a mile a little S. of E. a smaller pit, in a like place, showed the like thing.

Addendum.

Whilst this was passing through the press, a "Memoir of Caleb B. Rose," by Mr. H. B. Woodward, was printed,* with an account of his work and a list of his papers. To this the reader is referred for information about a pioneer-geologist of Western Norfolk, whose work is often quoted in these papers.

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* *Trans. Norfolk Nat. Soc.*, vol. v. pp. 387–403, plate (portrait).

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CHAPTER 4. UPPER CRETACEOUS SERIES.

The description of this great Series has been undertaken by MR. JUKES-BROWNE, who has for some years been specially engaged with Cretaceous beds, the notes of various colleagues being worked in. Chap. 6 however is only in part by him.

CLASSIFICATION.

The Upper Cretaceous rocks of this area have usually been described under two heads, the Gault and the Chalk; but, so long ago as 1883, S. WOODWARD separated the latter into three parts, the Lower or hard Chalk, the Medial Chalk, and the Upper Chalk. C. B. ROSE subsequently adopted these divisions and showed that each contained a different assemblage of organic remains (*Phil. Mag.*, 1835). [MR. R. C. TAYLOR seems to have had some such idea at an earlier date, for he says:—"The Chalk in the excavations around Swaffham belongs probably to some intermediate bed between the upper and lower strata."*—W.W.]

In 1876 DR. C. BARROIS published the results of his examination of the British Chalk, and showed that the classification proposed by D'Orbigny and adopted in France was applicable to England also, the three divisions of *Cenomanian*, *Turonian*, and *Senonian* being well developed in the Eastern and Midland counties.† The work of the Geological Survey in Cambridgeshire, published a few years later,‡ confirmed Dr. Barrois' conclusions and disclosed the fact that these divisions were separated by layers of hard rocky chalk, the outcrops of which were traceable across the country and could be laid down on the map. To one of these the name *Melbourn Rock* was given from the village where it was first examined in that district, the other was found to be the representative of the bed previously named *Chalk Rock*. It was then proposed to call the divisions thus established the Lower, the Middle and the Upper Chalk, and this nomenclature has since been generally adopted.

Each of these divisions of the Chalk has a chronological value which is at least as great as that of the Gault, and probably much greater, while lithologically and palæontologically they differ from one another quite as much as the Gault does from the Chalk Marl. The whole series in fact constitutes one great calcareous formation, for the Gault of Norfolk is much more marly than the mass of that clay to the south of the Fen-district.

In this Memoir therefore the Upper Cretaceous Series will be described as consisting of four stages or divisions:—1. The

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* *Trans. Geol. Soc*, ser. 2, vol. i., pt. i., p. 378. (1824.)

† Recherches sur le Terr. Crét. Sup.

‡ Geology of the Neighbourhood of Cambridge, by W. H. FENNING and A. J. JUKES-BROWNE, 1881.

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Gault; 2. The Lower Chalk, including the Chalk Marl and the Totternhoe Stone; 3. The Middle Chalk, based upon the Melbourn Rock; 4. The Upper Chalk, the base of which however has not yet been determined in Norfolk (except perhaps at one spot, near Swaffham), for the Chalk Rock appears to lose its special rocky character as it is followed northward, and its horizon has been identified to the north of the Lark valley only at the place alluded to.

In reading the older descriptions of the Norfolk Chalk it must be remembered that our divisions do not correspond exactly with those of WOODWARD. His Lower Chalk included all that was hard, *i.e.*, our Lower and the greater part of the Middle Chalk; his Medial Chalk was of considerable thickness but had no definite base or summit, and appears to have included the upper part of our Middle and a large part of the Upper or Senonian division.

GAULT.

General Account.

The existence of Gault in Norfolk was first pointed out, in 1835, by ROSE, who seems at first however to have had some doubt whether it was actually the representative of the Cambridgeshire Gault. His hesitation was entirely dispelled by WILLIAM SMITH, who recognised it by the fossils it contained *; so that we find DR. FITTON accepting its existence as established.† MR. ROSE afterwards succeeded in tracing the general course of its outcrop from West Dereham northward to West Newton (in Sheet 69).

From Fitton's time no doubt was thrown upon the occurrence of Gault in West Norfolk until 1886, when MESSRS. SHARMAN and REID raised the question and argued, from the character and contents of the bed, that it was the representative of the Chalk Marl and not of the Gault.‡ This suggestion was combatted by MR. W. HILL and the present writer, who proved it to be Gault by the the discovery of *Ammonites interruptus* in abundance near its base at Muzzle Hill, West Dereham, and of *Ammonites rostratus*, *A. lautus*, *Inoceramus sulcatus*, and *I. concentricus* in its upper and more calcareous part near Grimston. They also established the existence of true Chalk Marl in full force above the Gault at Stoke Ferry, and thus decided the age of the latter, not only by the test of organic remains, but that of actual infraposition to the unattenuated continuation of the Chalk Marl.§

In the southern part of the district the Gault is concealed by the Fen-deposits. It emerges from beneath these west of Stoke Ferry, and has a surface outcrop as far as Crimplesham, where

* *Phil. Mag.*, vol. vii. pp. 179, 180. (1835.)
† *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 312. (1836),
‡ *Geol. Mag.*, dec. iii., vol. iii. pp. 55–59.
§ *Geol. Mag.*, dec. iii., vol. iv. pp. 72–74 (1886), and *Quart. Journ. Geol. Soc.*, vol. xliii. p. 544.

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it passes beneath a broad mass of Boulder Clay. Emerging again near Fincham the outcrop can be followed by Shouldham and Marham, forming a strip of flat clayey soil between the Lower Greensand and the slope of the Lower Chalk. Thence it runs northward by Pentney and West Bilney, but its surface is largely covered by Post Tertiary gravels, sands and clays. Below Gayton and Grimston, however, it forms a narrow, but continuous, strip of land.

Near West Dereham the Gault is a marly clay, bluish-grey when freshly dug, but drying to a greyish-white, and then looking very like soft Chalk Marl. Its total thickness here is nearly 60 feet, and the higher part seems to be still more calcareous than the lower. There is a layer of phosphatic nodules at the base, which has been worked for many years.

By Shouldham, Marham and Pentney it is thinner, probably from 30 to 40 feet, but exhibits similar characters, being throughout a soft marly clay. The basement nodule-bed has not yet been found along this tract.

At Narborough House a well-boring shows 20 feet of marly clay identified as Gault (see Appendix, p. 158).

Near Gayton and Grimston its appearance is rather different, the lower part (indicated on the map by a darker tint) is darker and more clayey, while the upper part is very calcareous, containing 66 to 70 per cent. of calcic carbonate, and including layers of hard greyish-white limestone, in which the proportion of calcic carbonate is nearly 90 per cent. There is also a layer of red marl marking the beginning of the change into the Red Chalk of Hunstanton.

The following analysis of the red marl from Grimston was made by Dr. W. Johnstone.*

Silica and silicates - - -	22·6
Carbonate of lime - - -	69·5
,, ,, magnesia - -	·9
Sulphate of lime - - -	·66
Peroxide of iron - - -	3·4
Alumina and phosphoric acid -	1·6
Manganese - - - -	trace
Organic matter, etc. - -	1·34
	100

Details, south of the Nar.

Some of the junction-sections of the Gault and the Lower Greensand have been already described (pp. 13, 17). We now consider those sections more strictly belonging to the Gault.

In 1886, Mr. Reid published the following†: "The new Coprolite Works lately opened at West Dereham show the best sections of the Phosphate Bed and of the Marl immediately overlying it; but the Marl

* *Quart. Journ. Geol. Soc.*, vol. xliii. p. 588. (1887.)

† In a joint paper with Mr. G. Sharman, *Geol. Mag.*, dec. iii., vol. iii. p. 56.

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there is very thin, being partly cut out by Boulder-clay. In October, 1883, the section seen in the well was:"

	Ft.	In.
5. Boulder-clay, very chalky - - -	7	0
4. Blue marl, drying bluish white - - -	4	0
3. Coprolite Bed - - - - -	0	9
2. Hard loamy nodular Greensand - -	2	0
1. Running sand.		

"No. 3 is the bed for which the deposit is worked. It consists of a mass of phosphatic nodules in a greenish loamy or sandy matrix, partly derived from the underlying Neocomian Beds. Mixed with and occasionally imbedded in the nodules are numerous fossils. These fossils seem to be mainly derivative, for though most of them, as Mr. Teall has pointed out, belong to the zone of *Ammonites mammillaris*, there is apparently also an occasional admixture of older and newer forms, including some species, such as *Dentalium ellipticum*, probably belonging to the Gault."

"The "Coprolite" occurs in this bed in two forms. The more abundant is a poor sandy phosphate in irregular nodules," the other is a smooth dark phosphate in smaller nodules.

It is clear from this description that the two seams of nodules seen in the older working to the westward by myself in 1872, and by Mr. Teall in 1873 (see p. 13), run into one toward the north. I agree with Mr. Teall in thinking that the lower seam seen by us in the older working belonged to the zone of *Ammonites mammillaris*, and I believe that the occurence of only one seam in the newer workings, with a mixture of species, is due to current-erosion at the epoch of the *Ammonites interruptus* zone, whereby the fossils of the older bed were washed out and mixed up with those at the base of the Gault.

Messrs. Reid and Sharman imagined that the Gault was here absent, and that the bluish marl was Chalk Marl with a basement-bed containing fossils and coprolites derived from the Gault and Lower Greensand; but it was subsequently shown by Mr. W. Hill and myself that this supposition is untenable, and that there is ample evidence to prove that the marly clay overlying the coprolite-bed is really Gault.*

Coprolites have been dug in the field by the main road five furlongs south-west of the church, and here also there is a single bed of nodules overlain by 9 or 10 feet of marly clay.

In 1883 Mr. Reid noted that "the old coprolite-works near Dereham Abbey, and three quarters of a mile W.N.W. of the church showed no sections, but an abundance of specimens of *Belemnites minimus*, *B. attenuatus* and *Ammonites* were lying about."

I visited West Dereham again in 1886 and saw some new coprolite-pits in a field a mile W.N.W. of the church. At the north-eastern end of the trench the following succession was shown:—

Gault { Bluish-grey clay; 11 feet.
Dark sandy clay with phosphatic nodules; 9 inches.
Lower Greensand. Brownish sand.

The division between the sand and the nodule-bed was clearly marked and undulating; the phosphatic nodules were very dark but contained much quartz-sand. Fossils were not abundant, except fragments of *Ammonites Beudanti* and fibrous wood bored by *Pholades*.

For a certain distance, and over a tract of several acres as shown by trial-borings, the nodule-bed is cut out by a trough filled with Boulder Clay. The upper part of this clay is light-grey and full of chalk stones, while the lower part is simply re-constructed Gault and might be considered Gault in place if it were not for the absence of the nodule-bed (see fig. 1, p. 24.)

* *Geol. Mag.*, dec. iii., vol. iv., pp. 72–74, and *Quart. Journ. Geol. Soc.*, vol. xliii. pp. 547–549. (1887.)

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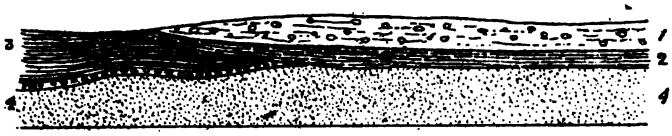
FIG. 1. *Section in a Coprolite Pit north of West Dereham.*



1. Boulder clay, with reconstructed Gault (2) at the base.
3. Gault, with phosphatic nodules at the base.
4. Lower Greensand.

A small outlier of Gault occurs on the hill about a mile W.N.W. of West Dereham, and about half a mile in the same direction from Muzzle Farm there is an old clay-pit, whence clay has been obtained for the purpose of marling the lighter land. The lower part of the face of the pit was hidden by talus, but there still remained a vertical exposure of 4 to 6 feet of marly clay containing many *Belemnites* and other fossils, but no *Ammonites*. However, by digging in the clay which forms the floor of the pit, *Ammonites interruptus* may be found associated with crushed *Inocerami*. The Ammonites are in the form of casts, the inner whorls having been filled with a light-coloured mixture of phosphate and carbonate of lime and the outer whorls with clay, so that there can be no doubt about their belonging to the bed in which they are found. Small black phosphatic nodules occur throughout the clay, and MESSRS. REID and SHARMAN state that "several years ago a trial boring was made in this pit for the "coprolite bed," and it was reached three feet below the floor; but only a few nodules were found and the bed was too thin to work." *

This outlier was recognised as Gault by FITTON, who noted "several pits, in a patch, or cap of bluish clay, over the Lower greensand," and recorded the occurrence therein of fossils and phosphatic nodules.†

At Shouldham the only sections are in a few deep ditches, and these show a marly clay, full of small *Belemnites*, like that around West Dereham.

In a ditch by the side of the wood about half a mile south-westward of the church MR. WHITAKER noticed grey marly clay with two coloured layers (one buff and 6 inches thick, the other buff and pinkish and a foot thick) and specimens of phosphatic nodules. *Belemnites minimus* and an *Ammonite* from this place were sent to him by DR. J. LOWE, formerly of Lynn.

Details, north of the Nar.

The following notes are also by MR. WHITAKER (to the upper part of p. 24).

A small ditch, running E. and W., about half a mile S.W. of Pentney Hall, but the exact position of which it was impossible to mark on the map, showed, at the eastern end, a thin scattering of gravel and sand over pale grey or whitish marl. Westward some pieces of grey clay had been turned out, and then *Belemnites*, phosphatic nodules, and irregular red ferruginous nodules. Farther on the bottom seemed sandy, and then there was thin Alluvium over clayey sand, some of which was greenish. This section therefore serves to fix the junction of the Gault and the Lower Greensand.

I understood that at Ashwood Lodge (? Pentney Hall of map) a thickness of 10 or 12 feet of blue clay [marl ?] was passed through before reaching carstone and sand.

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* *Geol. Mag.*, dec. iii., vol. iii. p. 58. (1886.)
† *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 312. (1836.)

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Rose has given the following section of a well at Pentney, but without stating the exact site, so that it comes better here than amongst the well-sections in the Appendix, as proving the Gault:—

		Feet.
Soil		4
[Gault chiefly]	Rubble chalk, succeeded by stiff blue clay, with *Belemnites minimus*	10
	Hard grey limestone, with *Terebratula biplicata*	½
	Very tenacious blue clay	2
[Lower Greensand.]	Black sand	1

He adds "From an old clay pit near Pentney church, I took two species of Belemnites"* (*B. minimus* and *B. attenuatus*).

Rose also says "The well at the school-house at Bilney passed through the same series of strata [as at Pentney], but . . the gray limestone inclosed *Inoceramus gryphœoides* and *Belemnites minimus;* the clay contained the same Belemnite, and also *Belemn. attenuatus.* W. W.

To the west of Gayton and Grimston the upper limit of the Gault is marked by the outcrop of the hard limestone from which several springs issue, and which forms the base of the Chalk Marl, while the lower limit is marked by the change from clayey to sandy soil. Along this tract the upper part of the Gault consists of a whitish marl which was at first taken to be Chalk Marl, and would have been so mapped had not a subsequent examination by Mr. W. Hill shown the existence of fossils which proved to be characteristically Gault species. These fossils occur in two bands of hard limestone which are found at the base of the marl and have a bed of pink marl between them. The soft chalky marl is about 10 feet thick, and the limestone-bands include a thickness of about 2 feet. The clay beneath is dark grey, becoming almost black at the base, and the thickness of this is 7 or 8 feet, so that the whole of the Gault is here reduced to a thickness of 20 feet. The lower clay has been separately mapped by Mr. Whitaker, for more than a mile: he says, however, that it was difficult to draw the line between it and the marly beds above.

The succession above described can be seen in the watercourse below Sow's Head spring, which rises from the hard Chalk Marl, S. of Grimston. Below this there is soft marly clay, and a little distance down two bands of hard yellowish-white rock cross the stream, the marl between them having a dull brownish-pink colour; the lower bed contains *Ammonites rostratus* and *Inoceramus concentricus.*

Mr. Whitaker notes that "in a small pond at the cottage half a mile a little W. of S. from Grimston church, may be seen some 4 feet of pale grey marl, drying white, the bottom part with many small *Belemnites* and some pieces of a large *Inoceramus.* The top part seems firmer and contains some hard blocks of a sort of sandy chalk, presumably from the hard base of the Chalk Marl."

"In a pond, at what seems to be an old brickyard, nearly half a mile westward of Grimston church, there are, on a mound (? remains of old pug-mill) many small *Belemnites*, small ferruginous nodules, some phosphatic nodules, and at one place some dark grey clay, from the lower part of the Gault."

The same beds as those seen below the Sow's Head spring are visible in the watercourse westward of Grimston. The outcrop of the lower hard bed occurs just by a small field-bridge about a quarter of a mile south-west of the church. This bed contains *Inoceramus concentricus* in abundance, together with *Ammonites lautus, A. rostratus, A. varicosus* and *Belemnites minimus.* Above it is a marly clay tinged with pink and full of the same Belemnite. The second hard bed was found above this, and higher up there is soft grey marly clay with occasional Belemnites, as far as the confluence of a small stream with the main brook, a little west of the church, where the hard base of the Chalk Marl comes in.

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* *Phil. Mag.*, ser. 3, vol. vii. pp. 180, 181.

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The following notes on outliers are by W. Whitaker.

South-eastward of Middleton whitish marly Gault crops out from beneath the Boulder Clay, and has been worked.

In saying that "on the heights between Middleton Tower and Devil's Bottom . . are patches of white and yellowish grey clay, containing many of the Gault fossils. . . In fact most of the heights in this part of the country are thinly covered with gault,"* Dr. Fitton is mistaken, the clay in question being either Boulder Clay or Drift brick-clay, except for the patch just noted. Rose too speaks of Gault "at East Winch, to the west of the church."†

Touching the high road, on its northern side, south of Chilvey House and about three quarters of a mile westward of Leziate, is a small overgrown pit, in which were seen, in 1883, irregular patches of brown, grey, whitish and red clay, with phosphatic nodules and small *Belemnites*, overlying sand. This clay seems therefore to be a patch of Gault low down on the flank of the Lower Greensand slope, a good way below the outcrop of the middle clayey beds of the latter, to the south. Whether this occurrence has been brought about by great irregularity in the original deposition of the Gault, on an eroded surface of the sand, or by a fault, or whether the mass may be merely a boulder, due to the Glacial Drift, is uncertain.

Rose speaks of an outlier of Gault "on a hill at Leziate, between the great road from Lynn to Gayton, and Pot Row, in the parish of Grimston"†; but this is probably Drift, not the wee patch of Gault just west of Pot Row (a name not on the map), next to be noticed.

In an old pit in the field on the hill-top over 1¼ miles west of Grimston church, there is, on the northern or higher side, a little clayey whitish marl; in the ploughed part reddish patches are shown; and in the bottom part dark grey clay. We seem therefore to have here both the marly and the clayey members of the Gault. At the south there may also be a little Boulder Clay.

The clay in a little old shallow pit just north, by the cottage, is probably Gault.

Just N. of Grimston Lodge there are signs of a patch of marl (? with some of the stone-bed at top). This seems to be slightly lower than the highest sand-pit at the eastern end of Roydon Common, close by.

About a third of a mile eastward of Grimston Lodge is a small old pit, on the eastern side of the track, some 8 feet deep in marl, which is in part broken up and disturbed. In the disturbed part there is an irregular layer of sand, about an inch to a foot thick, for a length of about 20 feet, in the marl, with some pinkish marl above, and, at one part, a broken-up stony layer. There is also a stony layer in the less disturbed part, lying horizontal, and going under the thin horizontal end of the sand-bed (which, where thicker, dips irregularly northward). The lower part of the pit was mostly hidden by fallen earth. In parts there are jambs of sand in the marl. Can this be a boulder, or a faulted mass?

A ploughed-over pit close by, separated only by the track, but at a higher level, seemed to show more of the stony bed in the marl, and also carstone.

Fossils.

Lower Gault { D = West Dereham.
M = Muzzle Hill, near West Dereham.
Upper Gault G = Grimston, Brook.

Pisces.

Beryx	D
Cimolichthys striatus, *Ag.*	D
Odontaspis gracilis, *P. & C.*	D
Pycnodus	D

* *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 312. (1836.)
† *Proc. Geol. Assoc.*, vol. i. p. 234.

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MOLLUSCA.

Cephalopoda.

Ammonites interruptus, *Brug.*	D	M	
„ lautus, *Sow.*	—	—	G
„ rostratus, *Sow.*	—	—	G
„ varicosus (?), *Mich.*	—	—	G
Belemnites attenuatus, *Sow.*	D	M	
„ minimus, *List.*	D	M	G
Hamites	D		
Nautilus	—	M	

Gasteropoda.

Aporrhais	D		
Dentalium ellipticum, *Brug.*	D		

Lamellibranchiata.

Anomia	D		
Inoceramus concentricus, *Park.*	D	M	G
„ „ var.	—	—	G
„ Crispii, *Mant.*	D	M	
„ sulcatus, *Park.*	—	M	G
Lima	D		
Nucula pectinata, *Sow.*	D	M	
Ostrea curvirostris, *Nills.*	D		
„ vesicularis, *Lam.*	D	M	
„ or Exogyra	D		
Pecten orbicularis, *Sow.*	D		
„ (Janira) quinquecostatus, *Sow.*	D		
Plicatula pectinoides, *Sow.*	D	M	

Brachiopoda.

Kingena lima, *Defr.*	—	M	
Terebratula biplicata, *Sow.* var. dutempleana, *d'Orb.*	D	M	G
Terebratulina gracilis, *Schloth.*	—	M	

ECHINODERMATA.

Pentacrinus Fittoni, *Aust.*	—	M	G
Pseudodiadema (spines)	D	M	

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CHAPTER 5. UPPER CRETACEOUS SERIES.

Lower Chalk.

General Account.

As limited by the classification now adopted by the Geological Survey this division is that part of the Chalk which lies below the Melbourn Rock. Palæontologically it can be subdivided into three zones; 1. That of *Ammonites varians*; 2. That of *Holaster subglobosus*; 3. That of *Belemnitella plena*. The first corresponds to the Chalk Marl, the second includes the Totternhoe Stone and the blocky chalk which overlies it, the third is a thin zone consisting principally of yellowish marl with discontinuous layers or broken lumps of hard white chalk.

The base of the Chalk Marl is generally glauconitic, but the number and size of the glauconite grains decreases rapidly to the north of Cambridge. It is still glauconitic at Stoke Ferry and at Shouldham, but the green grains are of very small size; north of this the glauconitic basement-bed appears to thin out and a white limestone without such grains rests directly on the Gault: it is this bed which forms the base of the rising ground by Gayton and Grimston. The remainder of the Chalk Marl consists of alternating beds of hard and soft chalk or marl, but the hard beds preponderate northward, or rather the marls appear to thin out. At Stoke Ferry the total thickness of the Chalk Marl is 75 feet, but near the northern border of the district, by Gayton and Grimston, it can hardly be more than 40 feet.

The Totternhoe Stone is represented by a band of tough grey and gritty chalk, with a layer of green-coated irregular-shaped nodules at its base, like those which form its basement-layer at Burwell, in Cambridgeshire. Its apparent sandiness is due to the presence of comminuted fragments of shell, which form from 60 to 70 per cent. of the mass; the percentage of quartz grains is very small, but grains of glauconite are present in some quantity. At Stoke Ferry it is about 4 feet thick, but it has not yet been seen at any other locality in this district.

Above the Totternhoe Stone there is some thickness of hard greyish chalk, irregularly bedded in the lower part, but blocky above, and passing upward into harder blocky white chalk. In this part of Norfolk this subdivision has a total thickness of from 40 to 50 feet.

At the summit of the Lower Chalk, and immediately underlying the Melbourn Rock, is a thin layer of yellowish marly chalk containing lumps of hard white chalk. This is taken to be the attenuated representative of the zone of *Belemnitella plena*, though the only fossils yet found at this horizon are *Rhynchonella plicatilis* and *Terebratula semiglobosa*.

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As it was not found possible to lay down the course of the Totternhoe Stone through this district, and as the pit-sections are not very numerous, especially on the south, it will be most convenient to take the exposures from south to north and to indicate the probable horizon of each.

Details, south of the Wissey.

There seems to be a small outcrop south of the Little Ouse, for in the ditch on the high road at Lakenheath Station, Mr. Whitaker found marly chalk, partly buff and a little pink; but this outcrop seems to be confined to the small island at the station.

The Lower Chalk then emerges from beneath the Fen along the tract between Hockwold and Hockwold Grange, being probably brought up by an east and west fault along the valley of the Little Ouse. There is a quarry by the main road a quarter of a mile north of Hockwold Church, exposing some 12 feet of uniform blocky greyish chalk without fossils; from its general characters and position this doubtless belongs to the zone of *Holaster subglobosus*.

On the northern side of Hockwold Grange (two miles west of the village), there is an old pit with a small weathered exposure of hard grey chalk, containing *Ammonites varians* and *Inoceramus latus* (*orbicularis*) in abundance, and this we have no hesitation in referring to the Chalk Marl, so that the outcrop of the Totternhoe Stone is to be sought for over the tract between these two pits.

By the roadside about a quarter of a mile northward there is a new quarry and lime-kiln, showing about 20 feet of blocky grey chalk, which has a greater resemblance to that which overlies the Totternhoe Stone than to any part of the Chalk Marl, and the only fossil found was *Ammonites rotomagensis*, which is not common in the Chalk Marl; this chalk may therefore belong to the zone of *Holaster subglobosus*, but if so there must be a cross-fault between this and the last pit, as the difference of level is very slight and the line of strike is nearly north and south.

Nearly half a mile farther north (beyond White Dyke) there is another shallow pit exposing hard grey chalk, in thin beds with lumpy irregular surfaces, which has a certain resemblance to Totternhoe Stone, probably because it is largely composed of comminuted Inoceramus shells. Minute green grains are fairly abundant in these beds, and a specimen of *Ammonites Mantelli* was found, facts which favour their relegation to the Chalk Marl.

Similar beds are seen in a quarry at the lime-kiln south of Feltwell St. Nicholas, but a better section is here exposed, as follows:—

	Feet.
Chalky soil	1
Greyish-white chalk, rather hard	10
Hard grey chalk in thin irregular beds, mottled with pipings of darker tint	about 5
Softer and lighter-coloured blocky chalk	seen for 10

Adits or tunnels have been driven into the blocky chalk, the lower part of the hard beds being also removed, leaving the hardest beds to form the roof. No recognisable fossils were found here, but microscopical examination shows that green grains are present throughout, though not so numerous as at White Dyke. If these beds are the same as those at White Dyke, we must again infer the existence of a fault or flexure to account for their position at Feltwell, on a higher level and more than a mile to the east of the former place.

At Feltwell St. Mary, in the bank of a dry pond by the roadside, a quarter of a mile north-east of the church, there was a small but interesting exposure showing a band of pink chalk weathering yellow, beneath which is a course of very hard nodular chalk, overlying soft whitish chalk.

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This succession is the same as that found at West Row, near Mildenhall, in Suffolk, where a band of pink chalk, 4 feet thick, is underlain by hard and soft chalk in alternating layers.* The West Row beds are believed to belong to the zone of *Holaster subglobosus*, and the similar beds at Feltwell may therefore be referred to the same zone, and consequently would be above the horizon of the Totternhoe Stone.

There are small exposures of soft marly chalk near the border of the Fens, north-east of Feltwell and just southward of Methwold Hithe, and again in the small low island in the Fens, on which stands Northwold Fen House, but no other pits in the Lower Chalk were found over the tract lying between Feltwell and Whillington.

At Whillington there are quarries of some size, exposing a good section of the upper part of the Lower Chalk and the basement-beds of the Middle division. The beds here seen are as follows :—

	Feet.
Gravelly sand and rubble - - - - about	3½
Hard whitish rough rocky chalk, weathering into nodular lumps - - - - - - -	7
Band of buff marl, enclosing loose lumps or nodules of hard chalk - - - - - - - - -	1½
Very hard white lumpy chalk, breaking along vertical joints - - - - - - - - about	3
Hard white chalk, passing down into creamy-grey blocky chalk, which is nearly white when dry - - -	12

There are no hard and fast lines between any of these beds, but the marl band forms a marked line of separation. The rocky chalk above has the structure of the Melbourn Rock of Cambridgeshire, and consequently the marly layer may be regarded as the representative of the *Belemnitella* Marl of that county, and the chalk below as the equivalent of that in the highest part of the well-known Cherry Hinton quarries; it is, however, very much harder than the corresponding beds near Cambridge. (It shows the curved fracture distinctive of Lower Chalk, and in contrast to the bedded chalk above. W. W.) The only fossils found in it were *Holaster trecensis*, *Discoidea cylindrica*, *Terebratula semiglobosa* and *T. squammosa*.

Mr. Cameron notes that the Lower Chalk (Chalk Marl?) has been quarried in the island of How Hill, in Northwold Fen.

Details, between the Wissey and the Nar

We find a good section of the central part of the Lower Chalk in the quarries north of Stoke Ferry, and the only one in this part of Norfolk where the Totternhoe Stone has been seen. Rose probably refers to this stone in saying :—"A grey bed at the base of the Lower Chalk denotes the position of the Chalk-marl; it may be seen in the large quarry at Stoke Ferry."† Mr. Whitaker, however, was the first to definitely recognise the occurrence of the Totternhoe Stone here, in 1882, but he did not publish any description of the section. The writer, accompanied by Mr. W. Hill, visited the locality in 1886, and their observations were published in the paper already referred to. They obtained permission to have a boring made from the floor of the principal quarry, to ascertain the total thickness of the Chalk Marl, the nature of its basement-bed, and the depth at which the Gault occurred. The complete section, obtained by uniting the results of this boring with the measurements taken on the face of the quarry above, are shown in Fig. 2.

* See Memoirs of the Geological Survey. The Geology of Parts of Cambridgeshire and of Suffolk, pp. 39, 40. (1891.)

† *Proc. Geol. Assoc.*, vol. i., no. 8, p. 232. (1862.)

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FIG. 2. *Section at Stoke Ferry.*

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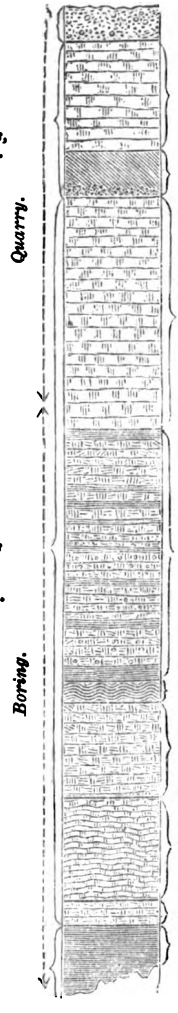
Scale, 20 feet to an inch.



		Feet
	Quarry.	
	Soil and gravel about	4
Zone of *Holaster subglobosus*, 16 feet seen.	Hard whitish chalk passing down into greyish bedded chalk	11
	Tough grey sandy looking chalk, becoming harder below and containing many yellowish phosphatic nodules* at the base (Totternhoe Stone)	4
	Band of mottled grey and white chalk	1
	Hard whitish chalk without definite bedding, weathering to a rough lumpy surface with a yellowish tinge	22
	Boring.	
	Rubble of broken chalk	2
Zone of *Ammonites varians* or Chalk Marl. 75¼ feet.	Hard greyish shelly chalk, with interbedded softer layers	14
	The like with buff stains or blotches, hardest in the lower three feet	12
	Softer chalk, grey and marly, mottled with paler bluish-grey material	2
	Hard light buff chalk, shelly, with black streaks (? oxide of manganese), passing down into less hard and less shelly dull grey chalk	10
	Soft whitish marl, with a harder lump here and there, but mostly cutting like cheese	11
	Tough grey sandy marl with yellowish streaks, containing glauconite grains and small phosphate-nodules	2½
Gault	Stiff dark blue clay proved to	1½
		7

* I should describe these rather as cream-coloured, and some are partly greenish outside The stone weathers out somewhat, though not very well-marked, and shows a slight easterly dip. W.W.

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The chief interest of the boring centres in the discovery of a definite glauconitic basement-bed resting directly on the Gault and consequently analogous to the well-known Cambridge Greensand, with which it is in all probability absolutely continuous. If a few borings were made through the Fen deposits along the line of strike the gradual change from one type to the other would doubtlessly be demonstrated. The basement-bed here differs from the Cambridge Greensand chiefly in its fineness of grain and in the absence of large phosphatic nodules; Mr. W. Hill, who examined its microscopical structure, describes it as a marl "containing an abundance of glauconitic grains, with some mica-flakes and fine quartz-sand, but these materials, particularly the glauconitic grains, are smaller and finer than in the greensands of Bedfordshire or of Cambridge." Only one phosphatic nodule was brought up in the cores, and that was a small specimen of *Avicula gryphæoides* in dark phosphate.

The overlying 11 feet of soft marl does not call for any comment except that it seems to die out northward.

The succeeding 10 feet is hard, especially in its upper portion, and has a yellowish tinge and a compact texture. Mr. W. Hill reports that foraminiferal cells are abundant in it, but that grains of glauconite are very few and small, though they are abundant in the beds above and below; it has in fact a special structural aspect which is different from that of ordinary Chalk Marl and bears a greater resemblance to the chalk of the higher part of the *Holaster subglobosus* zone.

The middle portion of the Chalk Marl consists of alternating beds of hard shelly chalk and softer more marly material; the shelliness is a microscopical structure hardly visible as such to the naked eye, but making itself felt in a grittiness or sandiness to the touch.

The highest part of the zone consists of hard blocky dull white chalk, which has a yellowish tinge on the weathered surface, is hard enough to resound under the hammer, and is about 24 feet thick. *Ammonites varians*, *Inoceramus latus*, and other fossils occur in this compact chalk, and a specimen of *Holaster subglobosus* was found, this being the first locality north of the Thames Valley where that species has been obtained from the representative of the Chalk Marl. Still further north, where all the Chalk Marl becomes hard and shelly, it is common. The rock exposed at Stoke Ferry is seen to contain many minute shell-fragments and a fair sprinkling of small glauconite-grains, when examined under the microscope.

The Totternhoe Stone has no definite base or top. It passes down into the hard chalk beneath by a kind of interdigitation, the darker grey material of the stone being piped into the light-coloured rock; the limits of the two materials are well defined, as if the latter had been drilled into deep irregular holes before the deposition of the Totternhoe Stone. The whole forms in section a band of mottled chalk about 12 inches thick, which splits into large blocks, together with the homogeneous grey stone.

In the layer of yellowish nodules at the top of this mottled chalk *Rhynchonella mantelliana* and *Terebratulæ* are common. In microscopical structure the mass of the stone is similar to that of Cambridgeshire, consisting mainly of comminuted shell-fragments, with many glauconitic grains and only a small percentage of fine quartz-sand.

Above the Totternhoe Stone there is a graduated but rapid change into greyish-white bedded chalk, and the proportion of shell-fragments rapidly lessens.

The ridge formed by the hard beds of the Chalk Marl, with the Totternhoe Stone above, runs north-westward for some distance from Stoke Ferry; but near Wereham it is capped and partially masked by a thick deposit of Glacial gravel. About three furlongs N.N.E. of Dereham Church a quarry gave the following section, the Drift, having been

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noted by Mr. Whitaker, who remarks on the general broken-up appearance of the chalk (1883):—

	Feet.
Drift. At the higher part two hollows of sand, with a little gravel, also a clayey layer and flints. At the base of another hollow, close to the road, a little grey boulder clay.	
Soil and chalk rubble - - - - - -	3½
Rather hard grey thin-bedded gritty chalk - - -	3
Hard marly chalk, weathering yellowish, with a rough lumpy surface, some of the lumps being very hard -	up to 12

One of the workmen said that he had dug a hole to the bottom of the Chalk, through hard rocky marl, reddish marl, and soft greenish-grey marl; but this was filled in, so that the beds could not be seen.

The lower beds seen resemble the hard Chalk Marl of Stoke and the higher have some resemblance to Totternhoe Stone, but they are thin-bedded and there are no phosphatic nodules at the base, such as invariably occur at this horizon in Norfolk, Suffolk, and Cambridge. It is probably therefore one of the hard shelly beds of the Chalk Marl (as Rose concluded*) like those passed through in the boring at Stoke. *Holaster subglobosus, Pecten orbicularis, Plicatula inflata, Inoceramus latus,* and a small species of *Avicula* were obtained here, and Mrs. Roper of Wereham has other fossils said to have come from this quarry, among which is *Pecten fissicosta.*

To the north and east of this quarry there is a wide spread of Boulder Clay, but the upper part of the Lower Chalk is exposed to the west of this, and the Chalk Marl emerges from beneath it on the northern side of Fincham, extending thence toward Shouldham, where its basal beds form the ridge on which the church stands. A small pit by the roadside about a sixth of a mile south of the church shows some 6 feet of rather hard yellowish chalk in lumpy irregular beds, overlying 2 feet of soft grey shaly marl, which is full of small green glauconite-grains, and contains in the lower part many small green-coated phosphatic nodules, together with *Avicula gryphæoides* in some abundance. This glauconitic marl is similar in all essential points to that found at the base of the Chalk in the Stoke Ferry boring, and there can be little doubt about its being a continuation of the same bed.

It will be noticed, however, that the basement-bed is not here overlain by soft marl, as at Stoke Ferry, but by hard buff chalk, such as occurs from 16 to 21 feet above the glauconitic marl at that place; it would therefore appear as if this soft marl had thinned out northward, or had changed its character, and, by the diminution in the quantity of fine silt, had passed laterally into a more purely calcareous and solid rock. Sliced and placed under a microscope the rock is seen to consist largely of fine amorphous material, that forms a matrix in which single spheroidal cells are conspicuously abundant; with these are some perfect Foraminifera and a few fragments of shell; grains of glauconite are absent. [On account of the dry summer, in 1886, this pit was dry, the lowest part being a pond in ordinary times; so that the bottom could be seen, and then many phosphatic nodules were found. The hardness of the Chalk Marl here seems not to have escaped the notice of Mr. C. B. Rose, who said that at Shouldham "blocks of an exceedingly hard nature are irregularly distributed through the softer marl; their solidity defies the blows of the quarrymen, and they are not convertible into lime by the heat of the kiln."† W. W.]

The glauconitic basement-bed has been seen also west of Marham.

Returning now, to follow the upper part of the Lower Chalk, we find this exposed in a quarry south of Barton Bendish, the western face of which shows from 25 to 30 feet of greyish chalk, becoming whiter upward. Some 10 feet from the base a band of harder grey chalk occurs. There is a slight dip eastward, bringing in higher beds with the rise of

* *Proc. Geol. Assoc.*, vol. i. no. 8, p. 232. (1862.)
† *Phil. Mag.*, ser. 3, vol. vii. p. 277. (1885.)

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the ground in that direction, and at the north-eastern corner the section is as follows:—

	Feet
Thin soil, with hard nodular rocky chalk below, weathered into rough lumps	4
Yellowish gritty nodular rock, passing down into whiter nodular rock, with marly chalk and greyish marl at the base	1½
Very hard rough white chalk (about 8 feet), passing down into greyish-white chalk which has a smoother fracture	12

The marly layer contains *Rhynchonella plicatilis*, and is identical with the layer which was taken to be the representative of the *Belemnitella plena* zone at Whillington. The other species noted in the list on p. 36 are from the white chalk below.

At the lime-kiln about a mile south of Marham the section is almost an exact repetition of that at Barton Bendish. The band of yellow chalk and marl is just the same thickness, and the hard white rock below forms a cornice which overhangs the greyish blocky chalk into which its lower part passes; at the northern end of the quarry the white and the grey portions are separated by a marked layer of hard nodular rock, but this is not continuous, dying out southward.

A little north of this quarry are the two cottages, for which the well, noticed on p. 158, was sunk. As the cottages are very little below the level of the Melbourn Rock we may estimate the thickness of the Lower Chalk here at about 90 feet, which is probably 30 or 35 feet less than its thickness at Stoke Ferry. No trace of the Totternhoe Stone was seen in this neighbourhood, but we should expect that bed to occur about 50 feet below the Melbourn Rock, and its outcrop should run along the slope of the hill toward Marham Church.

South-eastward of that church there is a large quarry which shows the same succession as to the southward, the section being as below (partly from Mr. Whitaker's notes). Fossils are very scarce.

- Hard rocky chalk, fissile, with cream-coloured layer at base.
- Soft marl and marly chalk, pale greenish.
- Projecting band of hard white chalk; 8 or 9 feet, passing down into the next.
- Greyish chalk, less hard than the above.

The upper part of the Lower Chalk is exposed in a pit half a mile south of East Gate, between Marham and Narborough, and in another south-east of Narborough.

Details, north of the Nar.

Over the low ground northward of Narborough no exposure was seen before reaching Gayton. Here are several quarries on the northern side of the village, the one principally worked being on the eastern side of the lane, rather more than a quarter of a mile N.N.W. of the church. It is in two levels, which, though separated by a considerable interval, form a really continuous section of nearly 50 feet in depth. The upper white part is here thicker than it is to the south, and is separated from the grey by a bed of marked character. The section is as follows:—

Upper Pit.	Feet.
Soil and rubble	1
Dull white, thin-bedded chalk, rather tough and weathering into thin platy or flaggy pieces	20
Lower Pit (beneath a foot of rubble).	
Firm white chalk, in thicker beds	12
Hard chalk, forming thick beds, but parting along greenish marly lines	2½
Greyish marly chalk, in massive beds	12

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MR. WHITAKER says of this pit that "its great interest lies in the fact that small boulders of granitic, gneissic and trap rocks are found in the chalk, an occurrence of most exceptional kind, unique in our district, and far beyond; though a great variety of stones has been found in the nodule-bed, at the base of the Chalk, round Cambridge. There were in 1882 a few large pebbles, up to 9 inches in length, lying in the pit. These are said to be found in the Chalk, at some depth, and there is certainly no other apparent source for them, the Chalk being quite bare. The workmen use them as anvils whereon to break up the chalk, for lime-burning. I took away one, and on a later visit several others, which are now in the Jermyn Street Museum."

MR. WHITAKER also notes that "The disused large pit to the west, on the other side of the lane, is in hard chalk, to water, which is touched in a hole in the lowest part." The lowest chalk seen is hard, greyish and gritty, and as it proved, when examined (by MR. HILL) under the microscope, to contain green grains, it is probably close to, if not actually the top of, the Totternhoe Stone.

The basal bed of the Chalk Marl is exposed in the watercourses just below the spring-heads at and south of Grimston. At the Sow's Head spring the water issues from a very hard solid limestone in thick beds, which weather to a creamy-yellow tint. This limestone contains small Belemnites in some abundance, and a small *Rhynchonella*, a variety either of *Cuvieri* or *mantelliana*. MR. W. HILL reports that under the microscope the structure of this rock is seen to be fine-grained, the mass of it being a fine amorphous calcareous paste or consolidated ooze. Single spheroidal cells and more or less perfect Foraminifera are abundant, but these and a few shell-fragments form hardly 25 per cent. of the material. It is in fact a still purer and more compact form of the rock which overlies the glauconitic marl of Shouldham. Nothing like this marl is to be found at Grimston, the hard limestone resting directly upon the soft whitish marls of the Upper Gault, without any marked plane of division, though the change from one kind of rock to the other is rapid.

The same hard creamy limestone is seen at the confluence of the watercourses west of Grimston Church.

At the main spring-head to the north there is a hard grey bedded rock, very gritty and shelly; thus resembling the shelly layers in the Chalk Marl at Stoke Ferry, and still more the hard shelly chalk known as the Inoceramus Bed at Hunstanton, which occupies a similar position.

About half a mile south-east of Grimston Church an old quarry was noticed by MR. HILL and MR. WHITAKER, showing hard smooth white chalk overlain by very hard and rough yellowish chalk; the latter has the structure of the Melbourn Rock and the former would therefore appear to be the uppermost part of the Lower Chalk; but nothing like the horizon of the *Belemnitella plena* zone was visible. As, however, this zone certainly disappears in the district to the north it may be absent here, for, as will have been gathered from the preceding account, the general tendency of the change in the Lower Chalk, when traced toward the north, is to lose its marly beds and silty ingredients, becoming more and more purely calcareous and acquiring a harder and more consolidated structure.

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Fossils.

B = Barton Bendish. D = West Dereham.
S = Stoke Ferry. W = Whillington (Northwold).

	Chalk Marl.	Totternhoe Stone.	Grey and White Chalk.
Cephalopoda.			
Ammonites lewesiensis (?), *Mant.*	—	—	— S
„ Mantelli, *Sow.*	D		
also from Marham and Shouldham (according to Rose).			
„ varians, *Sow.*	— S		
Lamellibranchiata.			
Avicula gryphæoides, *Sow.*	Shouldham	—	B?
Exogyra haliotoidea, *Sow.*	—	—	B
Inoceramus latus, *Mant.*	D S	S	
„ mytiloides, *Mant.*	—	—	B
Lima globosa, *Sow.*	—	S	
Ostrea frons, *Park.*	D		
„ vesicularis, *Lam.*	D		
Pecten fissicosta, *Etheridge*	D		
„ orbicularis, *Sow.*	D —	S	
Plicatula inflata, *Sow.*	D S	S	
Brachiopoda.			
Kingena lima, *Defr.*	—	S	
Rhynchonella mantelliana, *Sow.*	D S	S	B
„ plicatilis, *Sow.*	—	—	B
Terebratula biplicata, *Sow.*	— S		
„ semiglobosa, *Sow.*	D S	S	B S W
„ squamosa, *Mant.*	—	—	— — W
Echinodermata.			
Cidaris Bowerbankii, *Forb.*	—	—	B
Discoidea cylindrica, *Lam.*	—	—	— S W
Holaster subglobosus, *Leske*	D S	S	B S
„ trecensis, *Leym.*	—	—	B — W

In addition to the above the following fossils have been found; but their horizon cannot be given. They are either recorded by Dr. Wright (*Palæontograph. Soc.*) or by Messrs. G. Sharman and E. T. Newton, from specimens in the Lynn Museum, or are noted by Rose (*Proc. Geol. Assoc.*, 1862):—

Lamna subulata, *Ag.*, S.
Macropoma (coprolite), S.
Notidanus microdon, *Ag.*, S.
Turrilites tuberculatus, *Bosc* (Rose)? from Totternhoe Stone, S.
Lima echinata?, *Schloth*, S.
Ostrea vesicularis, *Lam.*, Gayton.

Pollicipes acuminatus, *Darwin*, S.
„ glaber, *Roemer*, S.

Serpula antiquata?, *Sow.*
Discoidea subucula, *Klein.*, very common (Rose), S.W.

Mr. Rose also said:—"In the lower beds of Chalk at Marham have been found two claws of *Astacus Sussexiensis* and part of a striated tooth with fragments of bone of some Saurian animal." (*Phil. Mag.*, ser. 3, vol. vii., p. 277.)

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CHAPTER 6. UPPER CRETACEOUS SERIES.

Middle and Upper Chalk.

General Note.

In the Middle Chalk of Cambridgeshire two zonal divisions were recognized in 1880, the zone of *Rhynchonella Cuvieri*, identical with Barrois' zone of *Inoceramus labiatus*, and the zone of *Terebratulina gracilis*. Subsequently certain alterations were made; the Melbourn Rock was included in the zone of *Rh. Cuvieri*, and it was thought that the upper part of the *Ter. gracilis* zone might be separated as the zone of *Holaster planus*.

In Norfolk the lowest of these zones can be easily traced, but no attempt has yet been made to trace the higher zones or to draw a line of separation between the Middle and the Upper Chalk, except quite locally. A. J. J-B.

At only one place, throughout the Norfolk outcrop (in Sheets 65 and 69 of the map), has the Chalk Rock been seen, and there only to the thickness of a foot. This, together with the absence of any marked feature along the escarpment (which is a more or less gentle slope), made the drawing of a line between Upper and Middle Chalk a matter of great uncertainty, and therefore it was left undone. W. W.

Zone of Rhynchonella Cuvieri. (A. J. J-B.)

The lower part of the Middle Chalk borders the Fen south-east of Lakenheath Station, and a small quarry three furlongs from the station shows thick-bedded hard chalk in which Mr. Whitaker found *Inoceramus mytiloides* and *Echinoconus subrotundus*. This chalk is probably from 10 to 20 feet above the Melbourn Rock.

On the northern side of Brandon Fen the Middle Chalk lies at a higher level, and the ridge above Hockwold and Wilton is probably due to the outcrop of the Melbourn Rock, but no exposure of this was found. Northward all the country as far as Methwold is covered by a drift of blown sand, even where Glacial deposits are absent, and there are no chalk-pits; so that the line drawn for the outcrop of the Melbourn Rock is purely conjectural.

At Methwold, south-east of the church, there is a large quarry, nearly 40 feet deep, exposing the hard rocky chalk of this zone, overlain on the western side by stratified sand and gravel. At the northern end there is less gravel and the section is as follows, the thickness being only roughly estimated :—

	Feet.
Soil, gravel, and disturbed chalk	4
Hard lumpy chalk, with two thin layers of greyish marl at the base	8
Hard yellowish nodular chalk, with *Rhynchonella Cuvieri* and other fossils	20
Talus below where lowest	5

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The bedding is nearly horizontal; and at the base a hole cleared of talus showed very hard rough and nodular yellowish rock, full of fragments of *Inocerami* and closely resembling the upper part of the Melbourn Rock of Cambridge and Herts.

At the western end of Northwold, and close to the high road, is a pit in the very highest part of this zone. It shows about 36 feet of much softer and whiter chalk with several thin layers of grey marl. The lower part is quarried for building-stone, which is said to stand very well if dug and squared when dry in the early part of summer, and many houses in Northwold are built of it. The uppermost 12 feet are soft and crumbling and contain many scattered flints, developed sporadically and not on any one horizon. The lower beds contain *Echinoconus subrotundus*, several species of *Inoceramus*, and a small circular variety of *Rhynchonella Cuvieri* (not the typical form). The whitening-works at Whillington are supplied with chalk from this quarry.

The next exposure is by the side of the road from Methwold to Whillington, and about three quarters of a mile S.E. of the latter place, where a pit shows about 12 feet of hard yellowish nodular chalk, like that at Methwold, and containing most of the same fossils; it cannot be far above the Melbourn Rock, which, as already mentioned, is exposed at the top of the quarries at Whillington (see p. 30). The rock there is hard, compact, and of a creamy white colour when broken, but weathering yellowish, with a rough nodular surface.

Mr. Rose has recorded the occurrence of *Ammonites peramplus*, Mant., at Whillington, one specimen with a diameter of 2 feet. This species must have come from the Middle Chalk of the pit.

The rock and the overlying chalk then pass beneath alluvium, and on the northern side of this they are covered by Boulder Clay, but in an old pit by the roadside north of Oxborough Fen there are lumps of hard yellowish chalk containing *Rhynchonella Cuvieri* and *Inoceramus mytiloides*, and evidently belonging to chalk near the horizon of the Melbourn Rock. The strip of Boulder Clay which flanks the eastern border of Barton Fen seems indeed to be banked against a ridge formed by the hard chalk of this zone, and thence it may be traced to the quarry south of Barton Bendish, where the base of the Melbourn Rock is actually exposed (see p. 33).

North of Barton Bendish the hard chalk of this zone caps the bolder and higher ridge which runs to Marham, and the basal part of the Melbourn Rock is exposed in the chalk-quarries at and south of that place (see p. 34).

Mr. Whitaker has noted an old pit, three quarters of a mile E.S.E. of Marham church, in weathered chalk without flints, rubbly at top, and with *Rhynchonella*.

From Marham the ridge bends eastward and sinks to lower levels, but the line of outcrop can be followed, and a small exposure of the rock occurs about two miles E.N.E. of Marham. Beyond this as far as Narford the feature is obscure and the line is conjectural. Between West Acre and East Walton there are several pits in massive white chalk without flints, and below them is a slight ridge which probably indicates the harder chalk of the Melbourn Rock.

Mr. Hawkins found a quarry in similar chalk without flints in Walton Field, seven eighths of a mile a little S. of E. of East Walton church. To be more precise, Mr. Whitaker and himself saw but two flints in it.

He also noticed the absence of flints in a pit about three quarters of a mile S.E., and in another a quarter of a mile N.E. of West Acre church.

The base-line is again fixed at Gaytonthorpe, where an old pit just S. of the church exposes hard nodular yellowish chalk without fossils (Melbourn Rock) to water. A large Ammonite (*Am. peramplus ?*) was found here by Mr. W. Hill.

The ridge is continued east of Gayton, and near its summit half a mile south-east of Grimston church an old pit exhibits hard smooth white chalk in the lower part, overlain by very hard and rough yellowish chalk. Microscopical examination by Mr. W. Hill showed the latter to have the structure of the Melbourn Rock.

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Chalk Rock. (W. W.)

The description of the solitary section of the Chalk Rock in Norfolk falls into place here, before we turn to the Chalk-with-flints.

The railway-cutting west of Little Friars Thorns and 2¼ miles and more W. of Swaffham is in Chalk-with-flints. About 70 yards east of the first (more easterly) bridge over, a hard cream-coloured semi-crystalline bed rises up, from beneath a layer of tabular flint. This bed is about a foot thick, of nodular character (like the Chalk Rock), and passes down into hard chalk, with another continuous layer of flints about 2½ feet below the top of the rock, which rises, beyond the bridge, to a point about 150 yards off.

The following fossils were found in the rock by MR. W. HILL and myself:—

- Lamna tooth.
- Inoceramus (pieces).
- Rhynchonella plicatilis (large var.).
- R. reedensis or mantelliana ?
- Terebratula, ? carnea and semiglobosa.
- Micraster.
- Coral.
- Sponge.

MR. W. HILL has examined this hard bed microscopically, and he tells me that it has the usual structure of the Chalk Rock, except that it contains no green grains.

The chalk below the rock is harder than that above, for some depth. More flint layers come in, some very prominent, until, at the next bridge over, Chalk with only here and there a flint (rarely seen) rises up, the ending of the flint-bearing Chalk being marked.

Chalk-with-Flints.

To the east of the tract which has just been described the Chalk contains flints in fairly frequent layers, and this belongs partly to the Middle and partly to the Upper Chalk; but as the line of division has not yet been traced, it is impossible to do more than give such notes as were taken by the officers who surveyed the country. Their notes have been arranged by MR. WHITAKER, chiefly from published descriptions by MR. SKERTCHLY (in the Gun Flint Memoir). A. J. J-B.

MR. SKERTCHLY has left some further notes on the Lingheath pits, a mile south-east of Brandon, whence flints were formerly obtained in large quantity for the flint-knapping industry, and these are incorporated in the following account, to the end of page 40 and pages 42–44 (top).

The flint now used for gun-flints at Brandon is obtained from Lingheath, about a mile south-south-east of the town, but it has, until of late years, been dug at Santon Downham, three miles further up the river, and at Broomhill about a mile from the town on the Norfolk side of the river. The flints occur in the Upper Chalk.

Lingheath is completely honey-combed with new and old pits, from Brandon Park, on the west, to the slope of the Ouse Valley, on the east. The pits in the latter situation are now worked out; they were shallower than those high up on the heath, a necessary consequence of their position. They are known as the *Fleet Pits* from this circumstance, *fleet* being a local term signifying *near the surface*, as distinct from *gain* meaning near at hand in a horizontal direction; fleet refers to vertical, gain to horizontal distances. These terms express two distinct ideas for which our cultured language has only the one word *near*. The flint has been worked on Lingheath for about 160 years (1879), prior to which time the stone was obtained from Brandon Park near the Elms.

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Fig. 3 is a section of a flint-pit measured by myself on the summit of Lingheath, in the Poor's Plantation, to which is added, from the information of old diggers, all the beds below the Floor-stone.

The chalk in this pit, which was the deepest worked for gun-flints in 1875, was dry, and the men found it drier among the trees. Roots of firs went down 15 feet into the chalk, in small pipes, not more than 6 inches across; and they seemed to dissolve the chalk by means of carbonic acid (in solution in water), the sand falling in as the pipes go down. The chalk was fairly firm and the burrows never timbered.

As usual the chalk hereabouts is intersected by many small faults; so that though the general dip is very small, being only about 1 in 88, the depth of the flint in adjoining pits varies 10 feet and more. The beds however are pretty persistent, and the layers of marl give a safe guide to the depth of the flint.

The flint-pits, no longer worked, were on Santon Downham Warren, opposite the Warren House, and near a barrow locally known as Blood Hill. There is another mound on Eriswell Rabbit Warren, near High Lodge Farm, which goes by the same name. The pits are on the slope of the valley-side, and are consequently shallow. The general section was as follows, in 1875; an explanation of the workmen's terms used will be found on pp. 42, 43:—

	Feet.
Sand and gravel	3
Dead lime [decomposed chalk], with a few floor-stones edge-ways, or on end, most of which had brown, glazed coats	5
Third pipe-clay	Trace.
Hard chalk	2
Floor-stone; very large flints, rich in "egg-shaped gulls," or *Paramoudras;* some of the stone milky in colour, like black flints changed by the sun. They were, however, good stone, and made good gun-flints	½ to 3
Soft chalk	3

Flint was dug formerly between the neolithic pits known as Grimes' Graves and Broomhill Plantation. The section in the modern pits is like that of the ancient; indeed very little variation can be traced in the sequence of the beds anywhere round Brandon. The pits were deep, but the chalk commenced below the horns. The following section was taken in 1875:—

	Ft.	In.
1. Sand and gravel, with a few palæolithic implements	3	0
2. Dead-lime, with a few brown-glazed edgeways flints	5	0
3. Soft, white chalk	3	0
4. Toppings flint	0	5
5. Soft, white chalk	3	0
6. First pipe-clay	0	1
7. Moderately hard, grisly chalk, with red stains	3	0
8. Upper crust flint	2 ft. to 0	8
9. Soft, white chalk	3	0
10. Second pipe-clay	0	1
11. Soft, white chalk	3	0
12. Wall-stone	1½ ft. to 1	0
13. Soft, white chalk, full of horns	2	6
14. Soft, white chalk	2	6
16. Third pipe-clay	0	1
17. Hard chalk	3	0
18. Floor-stone (flint)	3 in. to 0	4

Bed 3 in this section is the same as No. 5 at Lingheath. Bed 5 is thinner at this place, and beds 7 and 9 are thicker at this place than the corresponding beds at Lingheath.

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At Didlington a pit, half a mile east of the Hall, showed a hollow of sand and gravel over chalk with few flints.

About Bodney and Little Cressingham there are several pits, in all of which the chalk contains flints. One is rather over a mile south-east of Bodney. Another, nearly half a mile due east of Bodney Hall, Mr. Bennett notes as "showing 20 feet of rubbly chalk." There is another about three quarters of a mile east of the last, and a fourth about 20 feet deep, a mile south of Little Cressingham.

Mr. Rose has noticed that "exceedingly thin seams of flint are seen at . . Hilborough."*

Mr. G. Barrow notes that "the large spread of Chalk south and west of Swaffham is largely covered by sand and stones, in part the result of decomposition [of Boulder Clay] and in part drifted from other areas. The Chalk rarely comes quite to the surface, except on the brows of the hills. South of Pickenham Warren there are plenty of pits in chalk, which gets rather harder westward, toward Cley Hall (Cockley Cley), and contains fewer flints. In a pit near Gooderstone the chalk is still harder, and contains a yellowish clayey band some 4 to 6 inches thick. At Caldecote it is decidedly hard" [? Middle Chalk].

Mr. R. C. Taylor remarked that the Swaffham Chalk "presents one peculiarity in the disposition of the layers of flint, two layers, forming a pair, being set at the distance of a foot apart, and each pair at the distance of several feet from the next pair,"† and Mr. Rose noticed that at Swaffham "the tabular flints are of great magnitude, many of them being eight or more feet in length, and from nine to twelve inches in thickness."‡

At the lime-kiln by the southern side of the railway two miles west of Swaffham Station fossils have been found, and specimens may generally be got from the workmen, *Micraster coranguinum* and *Inoceramus* being plentiful. Many large flints occur in the chalk, and a large nodule of iron-pyrites was seen wrapping round a flint. A little bit of Boulder Clay, seen on the north, may be "tip" from the railway; but there is much rubble at top of the chalk, more or less festooned, in section.

Mr. C. E. Hawkins notes that "Chalk-with-flints may be seen in a pit half a mile N.N.E. of Great Friars Thorns; in another, in Narford Field, half a mile N.E. of the little wood marked 'Eye trap' on the map; and on Massingham Heath, a quarter of a mile N.E. of the 32nd milestone on the high road."

The following notes on the north-eastern corner of the district are by Mr. H. B. Woodward (1882 ?):—

"There are many pits near the Lexhams, Castle Acre, and Rougham, where the Chalk was formerly worked, but few pits now show a clear face of it."

"One of the best sections is in a pit about three quarters of a mile N.W. of Massingham Common, by the road leading from Great Massingham to Castle Acre. Here we find hard bedded chalk, with nodular flints, and clayey seams."

"A deep pit, in a plantation east of Fincham Farm, N.N.W. of Rougham, exposed chalk beneath the Boulder Clay; and in the same way it was shown in pits south of Weasenham Heath, and at West Lexham. Westward by Emmanuel Common the Chalk appears bare at the surface up to much higher elevations than it does to the north-east."

C. B. Rose says: "The black oxide of manganese is met with at Castleacre. I found this black powder lying in the natural separations of the chalk, about twenty feet from the surface; it occupies both the oblique and horizontal clefts, but is most abundant in the latter; it is accompanied by and partly mixed with brown oxide of iron and loose chalk."§

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* *Proc. Geol. Assoc.*, vol. i. p. 231.
† *Trans. Geol. Soc.*, ser. 2, vol. i. p. 378. (1824.)
‡ *Phil. Mag.*, ser. 3, vol. vii. p. 370. (1835.)
§ *Ibid.*, p. 373. (1835.)

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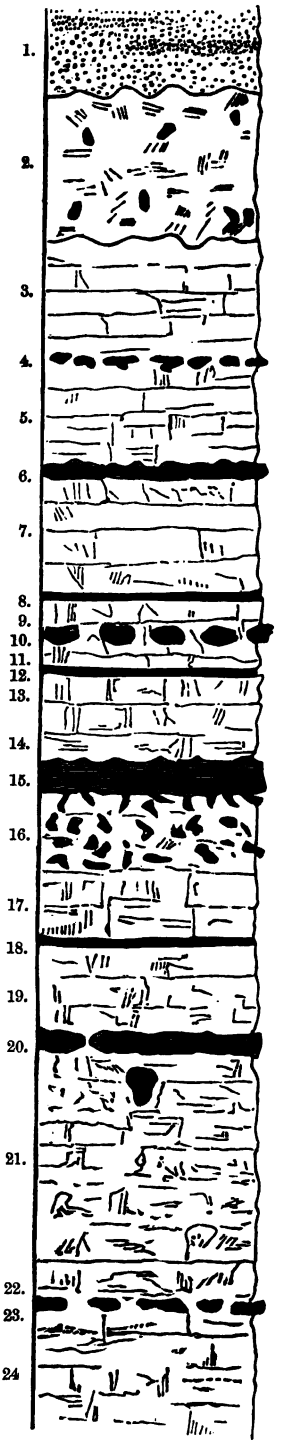
FIG. 3. *Section at Lingheath, Brandon.* (S. B. J. SKERTCHLY.)



	Ft.	In.
1. Sand and Gravel	3	0
2. Dead Lime: decomposed chalk, into which the sand penetrates, and with which its upper part is generally mixed. Friable above but lumpy below; small flints, with natural coats, are scattered through it. In fleet pits, where it intersects a layer of flints, the large flints are always edgeways, or stand on end, and often have brown glazed coats. The junction with the chalk below is more or less abrupt	5	0
3. Soft white Chalk of the ordinary character, and said not to make such good lime as the dead lime, which is always preferred for mortar. This applies also to 5, 7, 14, 21 and 24	4	0
4. Horns flint; an irregular layer of flints, which are nearly all small and finger-shaped; they seldom run to more than 3 inches in length, and half an inch in breadth. Thickness included in the following:—		
5. Soft white Chalk	3	6
6. Toppings Flint; the first regular layer of flint, more or less continuous, or forming, as the workmen say, a *sase* or *sese*. They are "hobbly" stone, that is, covered with "paps" or knobs on the top, but flat below. They break "grisly," that is grittily, and do not "run," or flake cleanly, and are "coarse working stone," that is to say, they do not cut clean, and will not make "best" gun-flints. Good pieces are occasionally found, and these are not hobbly but flat like floor-stone. Toppings are nearly always burrowed for in filling up the pit, and are worked from beneath, and they seldom come out in lengths of more than a foot	0	5
7. Soft, white Chalk, like 3	4	0
8. First Pipe-Clay. The *pipe-clays* are thin seams of marl, and are pretty constant, especially the lowest or third, which the workmen say rules the floor-stone; that is to say, when it is reached the floor-stone is known to be only 3 or 4 feet distant	0	4
9. Hard, white Chalk; a hard, subcrystalline limestone, which rings and strikes fire under the strokes of the pick: so hard that it cannot be picked on the solid face, but has to be worked from the joints. This applies also to 13	1	0

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	Ft.	In.
10. Upper Crust Flints; generally round and lumpy, and do not form a regular *sase*, but are dotted here and there in the layer; nearly always grey, without paps, and double coated, that is they have two distinct layers of cherty matter on the outside, which break away separately: these coats are sometimes parted by a thin layer of flint. Only used as building-stones, and merely taken out in sinking the shaft, but when building-stones are in demand they are burrowed for. They are not faced, but used rough, and are known as *rough builders* -	0	8
11. Soft, white Chalk, like 3 - - - - - -	1	0
12. Second Pipe-Clay (see 8) - - - - -	0	2
13. Hard, white Chalk, one jointless bed - - -	1	0
14. Soft, white Chalk, like 3 - - - - -	2	0
15. Wall Stone; always continuous or forms a "sase"; has "paps" above, and horn-like projections below called "legs," which are sometimes a foot long, and make the stone very difficult to raise. The pieces come away in long flat masses sometimes a yard square, generally black, but sometimes grey or spotted, and occasionally with a bluish "plumage," whence it is aptly termed "jackdaw" coloured. Nearly always of good quality, flakes well, with little waste, and hence only leaves small cores for "builders." Is burrowed from the top, as the legs would prevent it being worked from below -	1	0
16. Very soft Chalk, full of Horns so thick that the pick can hardly be used; often stained yellow. It is sometimes mixed with sand to render it stiffer, and is shovelled out	2	6
17. Soft, white Chalk - - - - - -	2	6
18. Third Pipe-Clay (see 8) - - - - -	0	2
19. Hard, white Chalk, sometimes only 2 feet thick, in which case 6 inches of soft chalk overlie the floor-stone -	3	0
20. Floor Stone; the bed to which the pits are sunk, and from which most of the gun-flints are made. It is generally continuous, but sometimes in ovoid masses which are called "heel-pieces," but even then the "heels" of adjacent stones are in contact. In some places paps are found on the top of the flint, but these are rough, and in this respect different from the paps of the toppings; such stone is called "rough-topped." Another variety has an undulating surface; such stone being called "hobbly-topped." These are very seldom heeled, and are easiest to get, because when they break away they always leave a face to work upon, and therefore no time is lost in picking chalk. Nearly always flat-bottomed, and thinnest when there are many heel-stones. When over a foot in thickness it is generally grey in the middle. Very rarely runs into great "harp-like" pieces 4½ feet across, which I take to be *Paramoudras*. They are so exceptional that when my informant found one, he sent for other diggers to look at the "curosity." He got a "jag" of stone from his curosity, that is, a one-horse cartload, about equal to a ton. More commonly, but still rarely, similar stones are found just below the floor-stone, which are described as "like gret eggs," and from each of which half a jag of stone can be got. They are called "gulls." Floor-stone is always burrowed for, and gulls too when they can be found - - - - - -	0	8
21. Soft, white Chalk, like 3 - - - - -	7	6
22. Hard, white Chalk, of similar material to 13; never worked into except along the burrows beneath the floor-stone; but trial-pits were sunk many years ago in search of flint - - - - - - - -	1	6

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	Ft.	In.
23. Rough and Smooth Blacks; large detached flints found 10 feet below the floor-stone in trial-pits sunk many years ago. They occur too sparingly to be remunerative. The smooth blacks were some of the best working stones ever raised; good in colour, clean-cutting, and of good running quality. The rough blacks were grisly and only fit for common gun-flints. The surrounding chalk is described as very hard - - - -	0	4
24. Soft white Chalk, like 3 - - - - - -	—	

Fossils.

The zonal divisions of the Middle and Upper Chalk of West Norfolk not having been worked out we are unable to give any lists of fossils, except the following, which includes such as have been recorded from the neighbourhood of Swaffham and to the north:—

Long lists of Upper Chalk, of Medial Chalk, of Hard Chalk, and of Chalk Marl Fossils are given by S. Woodward (Outline of the Geology of Norfolk, pp. 46–53), and by C. B. Rose (*Phil. Mag.*, ser. 3, vol. vii., pp. 278, 279, 374–376); but it is often difficult to translate the old names into modern palæontologic language.

C. = *Castle Acre.* From specimens in the Lynn Museum, determined by E. T. Newton, and from S. Woodward (Geology of Norfolk).

L. = *Lexham.* C. B. Rose (*Phil. Mag.*, ser. 3, vol. vii.) and S. Woodward.

S. = *Swaffham.* From the collection of the Geological Society, from the Lynn Museum (determined by E. T. Newton), and from the collection of Mr. J. King, of Norwich. Mr. Jukes-Browne writes that "the Swaffham list contains the names of the characteristic fossils of the lower part of the Upper Chalk, not far from the horizon of the Chalk Rock.

W. = *West Acre.* From the Lynn Museum, determined by E. T. Newton.

Beryx ?. W.
Enchodus lewesiensis, *Mant.*, (halocyon, *Ag.*) S.
Lamna (Otodus) appendiculatus, *Ag.* S.
Ptychodus mammilaris, *Ag.* S. W.
Nautilus elegans, *Sow.* L.
Pleurotomaria depressa, *Sow.* S.
Inoceramus Brongniarti, *Sow.* S.
,, Cuvieri, *Sow.* S. W.
,, involutus, *Sow.* L.
,, Lamarckii, *Park.* S.
Lima Hoperi, *Sow.* S.
,, spinosa, *Sow.* S. W.
Ostrea normaniana, *D'Orb.* S.
,, vesicularis, *Lam.* S.
Pecten nitidus, *Mant.* S.
Plicatula. S.
Spondylus. S.
Crania. S.
Rhynchonella limbata, *Schlot.* (Terebratula subplicata.) C.
Serpula. S.
Terebella lewesiensis, *Davies.* W.
Cardiaster ananchytis, *Leske* (noted by Wright as from Middle Chalk). S.
Cardiaster excentricus, *Rose.* S.
Cidaris perornata, *Forbes.* S.
Echinocorys vulgaris, *Breyn.* (=Ananchytes ovatus.) S.
Micraster breviporus, *Ag.* S.
,, coranguinum, *Klein.* C. S.
Camerospongia subrotunda, *Mant.* (Cephalites constrictus, *Smith*). S.
Coscinopora (Ventriculites) quincuncialis, *Smith.* C. S.

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CHAPTER 7. GLACIAL DRIFT.

General Remarks.

In our district the Glacial Drift consists chiefly of Boulder Clay, an undoubted product of ice-action; but there are also gravels and brickearth, which, either from underlying the Boulder Clay, or from being more or less associated with it, are classed as Glacial, though in themselves yielding no evidence of glacial action. In some cases the classification is doubtful, and must be taken as the best that could be done, rather than as a dogmatic statement: it simply seems more likely that various isolated patches of gravel, etc., belong to the Glacial Drift than to any other part of the Drift Series.

This Drift not only covers a large part of the higher grounds, but, with a marked disregard of level, reaches down many of the slopes, and occurs also in the lowest ground, underlying the alluvial beds of parts of the Fenland and of the Marshland, where indeed its extent is unknown. In places too there are deep channels filled with Drift, which, in the lower grounds, go to some depth below sea-level, and it is in these probably that the deposit reaches its greatest thickness; the sheets on the higher lands being, as a rule, of no very great thickness, as far as our information goes. The greatest recorded depth is 100 feet, in a well at Stow Bardolph, omitting the doubtful record at Swaffham (p. 61).

In the case of many patches of gravel it is impossible to be certain whether they are older than the Boulder Clay or not, as none is found either above or below them, some too being far from any Boulder Clay. Sometimes also, where a thin bed of that clay underlies a loam or gravel, we cannot tell but that it is one of those layers that occur here and there amongst those members of the Glacial Drift that underlie the great Boulder Clay of our Eastern Counties, and there is reason to expect the presence of such a layer in parts of our district. It must be understood therefore, that in attempting to classify the members of the Glacil Drift it is quite likely that gravels, etc., may be classed as older than the Boulder Clay, which really are not so: in some cases it is simply more convenient to take them under that head. Indeed some gravel that has been coloured as Glacial may be of somewhat later age.

Beds below the Boulder Clay.

South of the Wissey.

In that small part of the district that is in Suffolk, and south of the Little Ouse, but one patch of Drift that can be safely classed as below the Boulder Clay has been noted.

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Mr. Skertchly, writing in about 1876, says that "at Santon Downham there was a brickyard nine years ago, which is about to be re-opened. The section was as follows":—

Sand and gravel, 3 to 4 feet.

Glacial Drift. { Boulder Clay, 13 feet. / Blue clay, 4 inches. / Fine chalky gravel, 14 inches.

Chalk.

And in another note, referring perhaps to the same place, he says:—"Around the brick-kiln a mile south of Santon Downham Church there is a quantity of brickearth, sometimes at the surface. It has been dug to a depth of 10 feet, and good bricks have been made; but it lies in veins and cannot be mapped." There is indeed no note of the section on his working-map.

Patches of gravel in this small tract have been coloured as Glacial, but the largest two, westward of Brandon, would seem rather to belong to the Ancient River Series, to which a separate colour has been given in the map to the south (51 N.E.). It was thought, however, inadvisable to introduce that classification into Sheet 65, though the long line of gravel-cappings from our southern margin at Gravel Hill (Grave Hill of the map), by Methwold and Wereham to Crimplesham, is suggestive of an old watercourse. It may be well, therefore, to treat of these gravels after the Boulder Clay, the same colour having been used for Glacial gravels whether under or above that clay.

At Wilton High Barn, about 1¼ miles north-eastward of Hockwold church, the beds below the Boulder Clay seem not to crop out to the surface, presumably from being overlapped by the latter. The section is of interest as showing a lower bed of Boulder Clay. The following description is from Mr. Skertchly's notes.

"At Wilton Brickyard, on the hill-top at High Barn, there were two principal pits (? 1877), one south and the other north of High Barn."

"The southern pit showed sandy wash, from 2 to 3 feet thick, resting on red sandy clay, with small flints, about 8 feet seen. This clay is like the Norwich Brickearth or Lower Boulder Clay [a stony loam]. It is generally unstratified, but contorted in places, and contains, here and there, masses of buff false-bedded and contorted sand with black specks, which is interesting from containing a few fragments of marine shells, apparently of the genera *Tellina* and *Cardium*. On the western side of the pit Boulder Clay was seen overlying the sand and clay to a depth of 3 feet."

"The northern pit showed the relation of these beds very clearly, the section being as in Fig. 4, p. 47."

We now come to the consideration of some important sections, mostly in beds of a loamy character, and which Mr. Skertchly wished to name Brandon Beds, from the neighbouring town. As, however, the sections are of like kind to others, and often finer ones, elsewhere, there seems to be no good reason why a new name should be given where the term Glacial Loam is really enough. Moreover, were a local name needed, that of Brandon would hardly be the best, the sections being some way from the town. The following description is by Mr. Skertchly, who thought the sections of more especial interest from the occurrence of flint implements.

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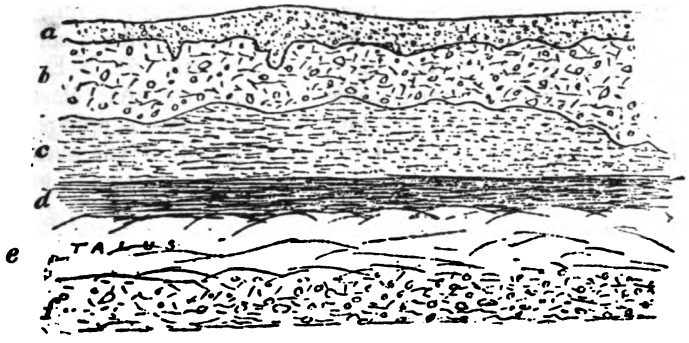
"The sections are in a continuous strip of loam, along a line from Broomhill, about a mile N.E. of Brandon, to beyond the neolithic flint-pits known as Grimes' Graves (wrongly marked on the map: they are not by the house, but in the wood some way to the N.E.). The loam has been worked for brick-making since Saxon times, and pits have been opened at different times all along the strip, so that there can be no doubt of the beds being of the same age throughout."

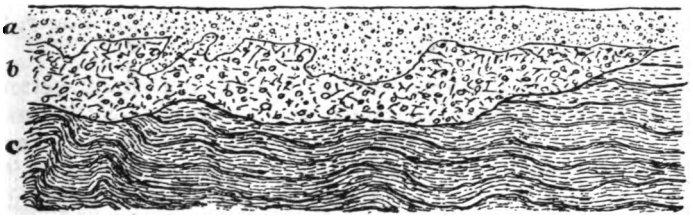
"The general relation of the sections is shown in Fig. 5" (p. 48).

FIG. 4. *Section in the Northern Pit at Wilton High Barn, Hockwold.*



a. Sandy soil.
b. Boulder Clay, very chalky.
c. Buff loam and clay.
d. Red clay.
e. Hidden by talus.
f. Boulder Clay, light-blue (like Gault in colour), full of large unworn septaria and with plenty of scratched chalk stones. Seen to a depth of 10 feet in a pit dug at the bottom of the great pit.

FIG. 6. *Section in a Pit at Broomhill Cover.*



a. Sand and gravel, say 3 feet.
b. Boulder Clay, almost entirely composed of fine chalk, with few scratched stones, but with some good specimens of glaciated chalk, say 4 feet.
c. Buff loam, finely laminated (with partings of sand); in places much contorted, say 10 feet.

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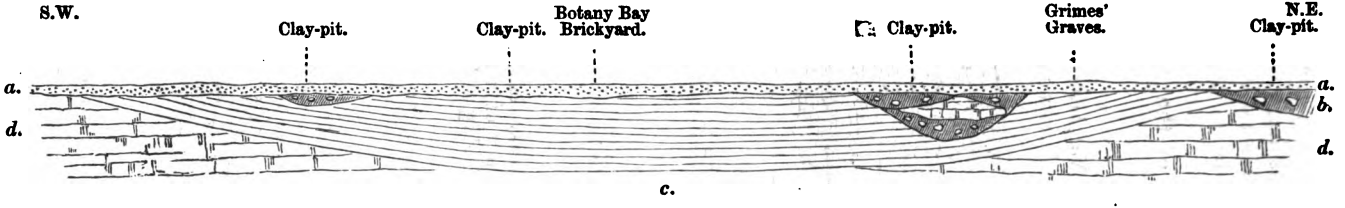
FIG. 5. *Sketch-Section north-eastward of Brandon.*

(No scale.)



a. Sand and gravel, with Palæolithic Implements.

Glacial Drift { *b.* Boulder Clay. *c.* Loam, etc., with Palæolithic Implements.

d. Chalk.

This section having been drawn (for the Gun Flint Memoir) before Boulder Clay was seen over the loam at Botany Bay, none is shown there.

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The section at Broomhill was tolerably clear, though the pit had not been worked for two years (? 1877). When clear it was as in Fig. 5, the unconformity between the gravel and the Boulder Clay, and that between the latter and the loam being well-marked.

"The Botany Bay brickyard is at the spot marked Grimes Graves on the old Ordnance Map. It was here that I got the first flint implement from these beds, and the chief interest of the place is the occurrence of implements. I have got altogether about a dozen implements and several flakes from this pit, some of which I dug out myself. They are, however, very rare. They are found scattered throughout the entire section, and frequently deeper than is shown in the figures. No shells have been found, but I got a fragment of a mammalian bone from a gravelly seam about 20 feet down."

"The beds are about 30 feet thick, and rest on the Chalk. The pits are worked to a considerable depth in winter, and are partly filled up again with waste material."

"No Boulder Clay was to be seen at first, but the brickmaker told me that patches used to occur, and this statement is borne out by the glaciated stones lying about. It was said to have been found near what is now the western face of the exposure, and the probability of this being the case is further strengthened by the crumpling the beds have been subjected to at that place, as shown in Fig. 7. It may be objected to this that the overlying bed is not contorted; but I will only remark that the undisturbed beds are mostly gravel, while the disturbed beds are clay, and that sands often seem unaffected whilst clays are contorted. On a visit with me, Mr. Whitaker at once recognized the beds as of Glacial character, saying 'there must be Boulder Clay close at hand.' I have since (1878) seen patches of undisturbed Boulder Clay lying upon the loam, and Herr A. Helland, who was with me, recognized its undisturbed condition and Glacial character."

Another note by Mr. Skertchly seems to describe this section as on the southern side of the pit, and from it the thicknesses given are taken.

This note continues thus:—"The first two implements I got were from this side of the pit, and the workman who found them told me that they came from depths of 16 and 20 feet respectively. Prof. J. Geikie and myself took an undoubted flake from the loam, at a depth of about 16 feet, and I have since found more than one, so that the occurrence of chipped stones in this bed is beyond question. The gloss upon their surface is distinct from that upon stones from the gravel."

"The implement in the gravel *b* was rolled, and probably derived from older beds. This gravel belongs to my Flood Gravel."

In another account this section seems to be described as on the northern side of the pit. From this note some particulars have been added in brackets; but instead of the lowest bed, the section is given thus:—

Fine chalky gravel, say a foot.
Cream-coloured loam.

The differences may be accounted for by the cutting-back of the pit, through which variations in thickness, &c. would be shown.

Of the implements found here Mr. Skertchly writes as follows:—

"The first implement I obtained from the loam, at Botany Bay, measured $10 \times 3 \cdot 5 \times 1 \cdot 7$ inches. It is oval, of a rich glossy brown, and has been formed from a pebble, traces of the original surface being observable at the butt-end. It is boldly, but not unskilfully chipped, the cutting edge having been re-chipped, and it is much rolled."

"Of others, from the same place, one measuring $4 \times 2 \cdot 5 \times 1$ inches, is a peculiar implement, made from a naturally-fractured flint, by chipping along one side, to make a cutting-edge. Another, $3 \cdot 5 \times 2 \times \cdot 7$ inches, is an ovoid implement, made from a very coarse flake, by a few bold skilful chippings. Another, $3 \cdot 25 \times 2 \times \cdot 75$ inches, was made by boldly chipping the back of a thick flake, the original flat side remaining intact. A long oval implement, $6 \cdot 5 \times 3 \times 2$ inches, has been skilfully fashioned by a few bold strokes."

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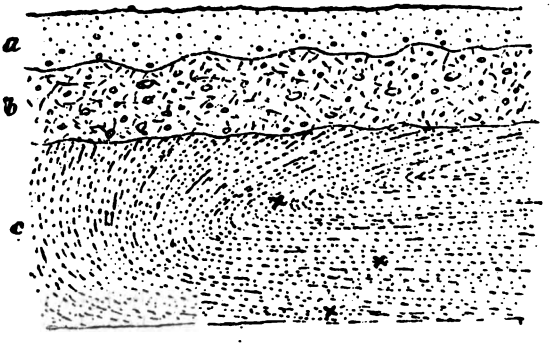
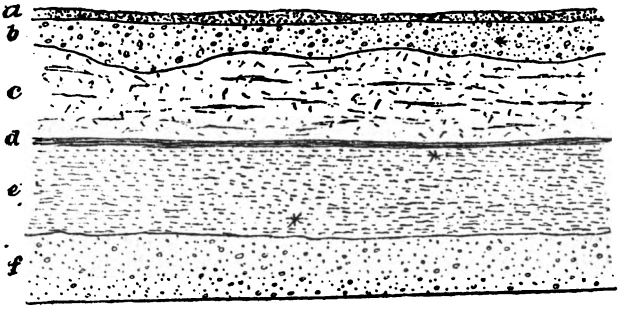
FIG. 7. *Section at the Western Side of Botany Bay Brickyard.*



a. Sand and gravel (3 to 5 feet).
b. Very stony clay (4 feet).
c. Cream-coloured loam, with implements at the spots marked × (15 feet).

FIG. 8. *Section on the Eastern Side of Botany Bay Brickyard.*



a. Sand (and fine gravel, 1 foot).
b. Sandy gravel, with flints (3 feet).
c. Red coarsely laminated brickearth (4 feet).
d. Carbonaceous layer.
e. Cream-coloured loam (with layers of sand, and with black specks here and there, 6 feet).
f. Sand and fine gravel.
× Implements, in *b* and *e*.

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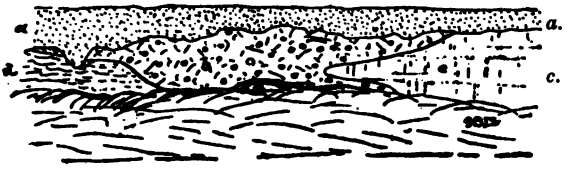
FIG. 9. *Section in a Pit west of Grimes' Graves.*



a. Sand and gravel.
b. Boulder Clay, very chalky; striated stones not common, but well striated septaria occur.
c. Boulder of chalk.
d. Buff loam, with sand.

"The old pit west of Grimes' Graves, now disused (1877 ?) was dug for the loam, and I had the face cleared, so as to find the lie of the beds where they had been hidden by talus, with the result shown in fig. 9."

"The chalk boulder on the right has been dug through, and Boulder Clay has been found beneath it. It was thought to be Chalk in place, by MESSRS. WHITAKER, WOODWARD, HARMER, FISHER, BELT, etc., notwithstanding the facts which I pointed out as conclusive as to its erratic nature, namely that it was more or less broken up, and contained flints of kinds never found together in place, but belonging to different layers that are separated by many feet of chalk. Large chalk boulders are common around Brandon."

"Good Boulder Clay was seen overlying the loam, at the eastern end of the pit."

MR. F. J. BENNETT notes that "at Croxton, there is an outcrop of loams from under the gravel, comparatively broad on the west of the village. The loam, in which there are old pits, rests sometimes on Chalk, sometimes on Boulder Clay [probably a lower bed]. A mile S.W. of the church is another old pit in the loam, and all these pits were made for raising earth to dress the land, a practice that has been left off." The sections just south, near Thetford, have been described in the Memoir on that part (1891).

Of the overlying gravel he notes that "there is a pit about a mile south-westward of the village, near the high road, showing about 4 feet of subangular gravel."

It is convenient to note here the patch of gravel nearly three miles to the north, of which MR. BENNETT says that the pit, marked on the map "a mile and a quarter S.S.E. of West Tofts, shows 10 feet of very coarse gravel."

Of the associated loam north of Croxton Heath he adds, "on the eastern side of the road, about a mile S.E. of Warren House, a pit, about 20 feet deep, showed buff sandy loam resting irregularly on stiff blue clay, and about three quarters of a mile S.S.E. of that house were two pits in buff loam."

"About a mile and a half west of Mouse Hall was a pit showing coarse gravel in a matrix of fine gravel and sand."

The relation of these beds to the Boulder Clay is doubtful, but the loams are like those that elsewhere underlie it, so that the clay beneath may be a lower bed.

The following note is by MR. SKERTCHLY, and the place seems to be about 1½ miles E. of Langford:—

"The Boulder Clay digs into and mixes up the loam below in a very instructive way. Above the spot marked × (fig. 10) it has the appearance of having been rolled over on itself, a not unusual thing."

"The loam passes from the usual buff kind into the mottled-and-sandy-parting variety, and, by the thinning out of the clay, into a fine sand. It is much contorted in places, and, as might be expected, has yielded much

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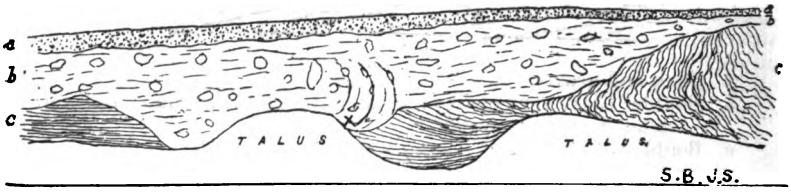
of its material to the overlying Boulder Clay, into which it seems to pass insensibly in some places."

FIG. 10. *Section near the House on Stanford and Tollington Warren.*

Depth 18 feet.



a. Sandy soil.
Glacial Drift. { *b.* Boulder Clay, with fold above × (middle).
c. Loam.

The patches of gravel at and near Bodney again are doubtful: of these MR. BENNETT says:—"The church stands on a hillock of buff sand, and there are three like sandhills southward."

"A mile and a quarter E.S.E. of the church was a pit in the bottom of a hollow showing 8 feet of very coarse much-worn gravel, with beds of sand in places."

"About a mile E.N.E. of the church is a small hillock of coarse cannon-shot gravel, seen to a depth of 4 feet."

The mapping of the strip a little northward points to the outcropping of the gravel from beneath the Boulder Clay. At Crimplesham gravel has been found in or beneath the clay. (See p. 63.)

Between the Wissey and the Nar.

In the first place the tract south-eastward of the Gooderstone Valley will be noticed and then the neighbourhood of Swaffham.

At Fouldon the Drift occurs at a low level (see p. 60), and beds below the Boulder Clay seem to crop out for some length, though for only a slight width.

The presence of Neocomian phosphates in the gravel shows that this Drift probably comes from the westward, where beds of that age crop out.

The old pit a little east of the farm (marked Barn on the map) about a mile westward of the church was mostly ploughed over in 1886; but one part, on the north, at the hedge-corner, showed the following beds:—

Soil.
Pale grey sandy Boulder Clay, up to 4 feet thick, split on the east by a wedge of gravel, the clay beneath whch was somewhat paler.
Chalky gravel.

From here the outcrop of the gravel spreads eastward, with but a slight gap, round the spur and back westward to Fouldon Fen House.

Some small shallow pits on a slight rise at the southern side of Fouldon Common, and a quarter of a mile north of Fouldon Fen House, were in chalky rubble (with sand and stones), sand (stony and chalky) and rubbly chalk, all more or less jumbled or squeezed together. At the most northerly part some gravel, that came on suddenly, consisted chiefly of chalk pebbles, flints, and small dark phosphatic nodules (derived from Neocomian beds). No definite order could be made out.

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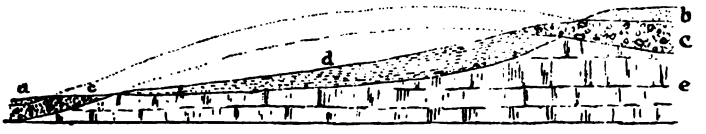
A pit about three quarters of a mile N.N.E. of Fouldon church was about 8 feet deep in chalky gravel, with flints, lumps of chalk, a fossiliferous Neocomian boulder, pieces of fissile Kimeridge Clay, layers of sand and a finer gravel (one such well marked and with many dark Neocomian phosphate-nodules). At the eastern end some beds were mostly of chalk, and the bedding was in the form of a hollow.

The following notes and figures (11, 12) are by MR. SKERTCHLY:—

"A patch of loam has been mapped north of Mundford, the only good exposure being at Didlington brickyard. The relation to the Boulder Clay was not clear in the pits; but it comes out readily on mapping the adjacent area. The loam, etc. occurs over an area of about two square miles, and a section from the river near Mundford, northwards along the high road to Hilborough, would show the lie of the beds to be as in Fig. 11."

FIG. 11. *Section northward from near Mundford.*

S. N.



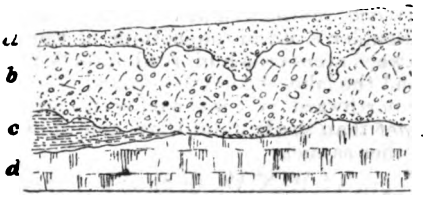
a. Valley gravel.
b. Flood gravel, a name given by Mr. Skertchly to some of the gravel above the Boulder Clay.
c. Boulder Clay. *d*. Glacial Loams. *e*. Chalk.

"The Boulder Clay is here seen to occur at the low ground, near the stream [as well as at the high ground], and I have dotted what seems to have been the original position of that deposit [across the tract between], showing how the loam has been exposed by denudation."

"That this lower patch of Boulder Clay does not crop out from beneath the loam is proved by the section shown in Fig. 12."

FIG. 12. *Section half a mile east of Ickborough.*

About 6 feet deep.



a. Sand and gravel. *c*. Loam.
b. Boulder Clay. *d*. Chalk.

"East and west the loam runs under and dies away beneath the Boulder Clay."

Two miles a trifle west of south from Swaffham Railway Station I saw gravel, sand and Boulder Clay over chalk; but presumably the Drift here could not be mapped."

Writing of the tract just southward and eastward of Swaffham MR. G. BARROW says:—"The sands and gravels in this area have few points of interest. The beds consist mostly of rounded flints, generally small, interbedded with sand, often somewhat loamy.

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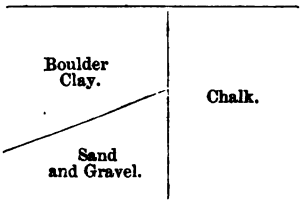
With the exception of the Cannon-shot gravel they seem to pass under the Boulder Clay, and the soil they make is for the most part like that made by decomposed clay."

"Near Snail's Pit Farm, about a mile S.S.W. of Swaffham, there was a large pit, the gravel in which rests on the Chalk. It is very irregularly bedded and some coarse lenticular masses are used for road-metal."

"An interesting section was seen at the cross-roads westward of South Pickenham, about half a mile N.W. of The Hall, where, in the field on the S.W. and touching the road, sand and gravel were clearly seen beneath Boulder Clay. The Drift abutted against the Chalk with a vertical junction, toward which the sand and gravel rose up beneath the Boulder Clay, but without reaching the surface."

"In the railway-cutting near North Pickenham there was a ballast-pit on the southern side, at the two ends of which there was some 20 feet of gravel, whilst in the middle chalk rose up and formed the floor. This chalk seems to continue eastward along the base of the cutting. On the opposite (northern) side of the railway chalky clay was to be seen; but a few yards west gravel comes on again in such a way as to suggest that it passes under the clay, though the junction of the two is nearly vertical. The gravel shows signs of contortion and contains many large flints: above it is what looks like decomposed Boulder Clay, to the thickness of two feet." I have seen Boulder Clay, with a loamy soil, clearly underlain by gravel in this cutting.



"S. and S.W. of Necton Hall there is a considerable spread of laminated clay, or brickearth. This bed underlies the surrounding gravel, for in several cases 2 or 3 feet of the latter have been pierced to reach it, and, taking into account the mode of occurrence and the surroundings of this clay, it seems probable that the deposit is older than the Boulder Clay."

Mr. Rose has remarked that "on Necton Common . . . the gravel beds contain so large a quantity of decomposing iron-pyrites, that the water percolating the gravel is sufficiently charged with iron to cement the sand and stony fragments together, and form a coarse breccia."*

Mr. Hawkins notes as follows:—"At Sporle, north-eastward of Swaffham, the Boulder Clay has been cut through, and consequently gravel and sand crop out for about three quarters of a mile along the bottom of the valley. Gravel was formerly dug on the eastern side of the road."

"At Farmers Wood, south-eastward of Sporle, gravel seems to come out from below the Boulder Clay, in the bottom of the side-valley. It may trend south-eastward across the high road into Necton Park, and gravel may be seen round the lake, though the ground not far off seems clayey."

Other patches northward of Swaffham seem, for the most part at all events, to be newer than the Boulder Clay, and it will be convenient to notice them together as such.

Whether the gravel W.N.W. of Stoke Ferry is older than the Boulder Clay or not is uncertain; but though at one place Boulder Clay seemed to occur over it, as noted by Mr. Cameron; yet, from this patch being in line with that by Wereham and Crimplesham, to the north-west (greater part of which is certainly newer than the Boulder Clay) and with the southerly continuation of patches by Methwold toward Brandon, of the age of which there is no evidence, it seems probable that the whole is more allied to the "Ancient River Gravels" of the tract to the south,† and it has

* *Phil. Mag.*, ser. 3, vol. viii. p. 29. (1836.)

† See "The Geology of Parts of Cambridgeshire and of Suffolk, pp. 72–75. (1891.)

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been suggested that at the section near Stoke Ferry the Boulder Clay may be a slipped mass. It will be convenient therefore to describe these gravels as a whole further on (see p. 73).

North of the Nar.

The following notes of the few small masses that seem to be older than the Boulder Clay are by Mr. Hawkins.

"There is a patch of gravel on the top of the hill about 1¼ miles E. of Gaytonthorpe church, capped by a smaller patch of Boulder Clay, as seen in a pit at the south-eastern corner of the wood, in which the chalky flint gravel has a few scattered pebbles of red chalk and shows signs of bedding though only seen to a small depth."

"On the opposite or eastern side of the valley is another patch of gravel, on the slope of the hill;" but there is nothing to show whether this is older or newer than the Boulder Clay.

A mile and more eastward from this are some beds that may crop out from beneath the Boulder Clay, round High House. "On the western side of the farm-buildings, belonging to the house, a pit showed a thickness of 4 feet of stony clay, over sand, seen to the depth of 10 feet. About 40 yards to the east, close to the pond, brickearth has been dug, to the depth of 10 feet. Southward of High House there is sand, in which are several obscure and overgrown pits."

"There is gravel at the edge of the Boulder Clay east of High House, reaching from the Peddar Way, close to which is an old gravel-pit, for nearly half a mile in the direction of Castle Acre Wicken Farm."

"There is also a trace of gravel at the edge of the small patch of Boulder Clay a few chains to the south."

"On the south-western side of Castle Acre Wicken Farm there again seems to be an outcrop of gravel from beneath the Boulder Clay, and a pit gave the following section":—

Loose angular flint gravel (with a little top soil); 3 feet.
Fine gravel and sand, inter-bedded and current-bedded; 7 feet.
Coarse flint gravel, with large flints and boulders of chalk; to 7 feet.

Mr. Woodward notes this as Cannon-shot gravel, and as "like many other little patches hanging on the edge of the valley, about the junction of the Boulder Clay and the Chalk. It is often difficult to determine the relation of these gravels to the Boulder Clay; but in most cases the gravel is the newer."

In 1865 Mr. S. V. Wood, Junr., noticed the occurrence of "Lower Drift" at Weasenham, and two years later he added Swaffham,* but he then said that the "Middle Drift" was absent, whereas it is to that division of his that the above-noticed gravels near Swaffham belong. However no details were given.

* *Quart. Journ. Geol. Soc.*, vol. xxi. p. 141, and vol. xxiii. p. 85

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CHAPTER 8. GLACIAL DRIFT.

Boulder Clay.

General Description.

In this district the Boulder Clay varies a good deal in character. Whilst in parts, including the lower grounds, we find the usual bluish-grey clay, crowded with small stones, and often having a considerable thickness in the channels which it fills; on the higher grounds of the Chalk the matrix is much less clayey and often mostly ground-up chalk, giving the deposit, here of less thickness, a markedly whitish tint.

Speaking of the neighbourhood of the Cressinghams, Mr. Bennett says "the Boulder Clay here is very chalky, and, as shown in pits, rarely reaches a greater thickness than 12 feet," and he notes an admixture of the two kinds of clay (see p. 58), which he regards as different deposits, "the westerly and more local one represented by the very chalky clay, the easterly and far-travelled one by the bluish clay."

Of the tract just northward Mr. Barrow says: "In the neighbourhood of Swaffham there is a large tract of chalky Boulder Clay, which really consists principally of pieces of chalk, with many small stones, in a marly matrix. Seen from a distance of 50 yards, or even less, a section in this would be unhesitatingly taken to be in chalk, so large is the proportion of that rock and so hard and white do the pit-sides weather." I remember, indeed, noticing on one occasion, in front of a good section of this deposit over chalk, that the Boulder Clay looked the more chalky of the two.

Going still further north, Mr. Woodward says: "North of Wicken Farm (northward of Castle Acre) and S.E. of Emanuel Farm (N.N.E. of Castle Acre) the Boulder Clay contains large lumps of chalk, and differs on the one hand from the more clayey kinds and on the other from the marly kinds. These seem to be simply local varieties of one deposit."

"The reconstructed appearance of the Chalk just beneath the Drift, that sometimes occurs, is clearly owing to surface-disturbance and weathering. It is like that which may be seen in the Chalk on the coast between Weybourn and Cromer, and it suggests that when the Boulder Clay was formed, the agent forming it may have found the top part of the Chalk already weathered. Hence the characteristic pellets, knobs, and boulders of chalk in the Boulder Clay may have often been got ready made, as it were."

Of the larger boulders found in our district the most interesting perhaps are blocks of sandstone with glauconite-grains, small phosphatic nodules and phosphatized fossils, and often showing, on broken surfaces, a peculiar lustre. These seem to

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have been first noted by the old Norfolk geologist, R. C. TAYLOR, as "large blocks or boulders of a grey or greenish sandstone, distinguished by its peculiar fossils,"* of which he names several. They seem to have come from the Lower Greensand of Lincolnshire, and from some of them probably came the fossils noted by MR. T. DAVIDSON, as follows†:—

"Several species of Brachiopoda have been met with in the Drift of Great Britain, but it has not always been possible to arrive at a positive conclusion as to the age of the rock whence these fossils have been derived. We refer more particularly to those that occur in the counties of Norfolk and Suffolk, and which are believed by some geologists to have been derived chiefly from the Lower Cretaceous and Upper Jurassic formations. I am not, however, aware of any rock *in situ* in this country wherein these species have been actually discovered." He then notes that Terebratula ovoides, *Sow.*, has been got from boulders in Norfolk, described by J. SOWERBY as "a sandstone containing green sand."

"Erratic blocks, containing *T. ovoides*, have been picked up in the Drift of several parts of Norfolk and Suffolk, especially at Gisleham near Lowestoft, and Thorpe in Suffolk; Stow Bardolph, Downham; Roslyn Pit, Ely; Feltwell, Norfolk, &c."

"A large and very convex *Terebratula* was found by Mr. C. B. Rose in the Drift of North Pickenham."

The subject was first alluded to, a few years earlier, by PROF. E. R. LANKESTER,‡ who stated that *T. ovoides*, etc., had been found in the Lower Greensand of Upware; but he, wrongly as I think, concludes that the blocks came from "the very highest of the Oolites," the fact being that the Neocomian beds of Lincolnshire were then little known to geologists.

Besides the stones already mentioned, the Boulder Clay contains many derived from Jurassic rocks, as well as from older rocks, such as Carboniferous sandstone and limestone, and various igneous rocks. Many of the included stones have the smoothed form and the scratched surface characteristic of glaciation, and there can be no doubt but that the whole deposit was ice-borne. Large boulders are rarely seen in sections, and we know of their occurrence chiefly from those left on the surface or in the bottoms of pits.

Of the tract round Swaffham MR. BARROW says: "The weathering of the Boulder Clay is characteristic. As a rule the soil of a chalky clay area consists of sand and stones, to a depth of 3 or 4 feet, or more, especially on the hill-tops. On a fairly steep slope it is not usually so far down to the chalky deposit, because there the rain has more power to wash away the sandy residue; whilst on the flatter ground it simply filters through,

* *Trans. Geol. Soc.*, ser. 2, vol. i. p. 374. (1824.)

† A Monograph of the British Fossil Brachiopoda, vol. iv., pt. i. Supplement to the Recent, Tertiary, and Cretaceous Species, pp. 9–11. *Palæontograph. Soc.*. 1874.

‡ *Geol. Mag.*, vol. vii. pp. 410–413. (1870.)

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dissolving the carbonate of lime and leaving the flints and sand. From the number of 'marl-pits,' from which the chalky clay has been dug for spreading over the land, there are many chances of noticing this weathering, and of seeing how this deposit resembles chalk in its tendency to form a soil that rests on it in pipes, etc., the whitish calcareous clay being very irregularly covered by the reddish product of its decomposition."

This is clearly analogous to the Clay-with-flints over the Chalk of more southern parts.

Sometimes, too, a loamy deposit occurs on the top of the Boulder Clay.

In many parts the presence of a sandy soil, spreading alike over the Boulder Clay and the Chalk, makes the line between these two very doubtful.

South of the Wissey.

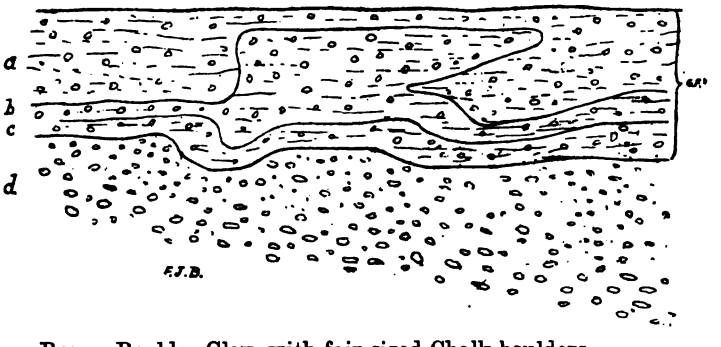
Mr. Jukes-Browne notes that "on the hill north of Hockwold there is a patch of Boulder Clay, in which a pit was opened, and the material was used in the construction of many cottages in the village, the clay being made up into blocks, with an admixture of straw, and dried in the air." The clay in this pit is light-coloured.

Mr. Bennett contributes the following notes:—

"On Croxton Heath are many pits showing from 8 to 12 feet of light-brown chalky sandy Boulder Clay, the boundary of which was most difficult to draw, mainly from the universal covering of sand, but also from the very chalky nature of the Boulder Clay."

"Near Great Cressingham there were many pits, opened for the purpose of marling the land, and so improving the character of the sandy surface-deposit that covers both Boulder Clay and Chalk. A pit on the high ground, a quarter of a mile south of Great Cressingham church, and on the northern side of the road, gave the section shown in Fig. 13."

Fig. 13. *Section in a Pit at Great Cressingham.*



a. Brown Boulder Clay, with fair-sized Chalk boulders.
b. Stiff bluish Boulder Clay. Seems to be contained, as a transported mass, in *a*.
c. White chalky Boulder Clay, with small pellets of chalk; 2 feet.
d. Chalky gravel; the top part fine, with many small chalk pebbles the lower part with large flints; not bottomed at 4 feet.

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"The gravel dips sharply toward the valley, northward; it seems to rise, as a boss, and to be included in the Boulder Clay, by which it is surrounded;" but it may be an underlying bed.

"Another pit, close by to the south, and on rather higher ground, was all in brown Boulder Clay; and another, on the other side of the road, a little to the west, showed 6 feet of chalky Boulder Clay, with small pellets of chalk (= *c.* of Fig. 13), with an included seam of gravel, and resting directly on chalk."

MR. BARROW notes that "on the steep slope of the valley of the Wissey, at Houghton on the Hill, the Boulder Clay comes close to the surface and forms a fairly stiff soil."

We now turn to some islands in the Fens, but east of the Ouse, and near the mainland.

The following note on *Hilgay* is by MR. SKERTCHLY (adapted from the Fenland Memoir):—

The Boulder Clay at this place is mottled yellow and light-blue, becoming darker blue with a few yellow mottlings at about 4 feet deep. It is very like Gault, and very free from boulders; chalk, millstone grit, and quartzite pebbles occur, none exceeding the size of a walnut. It is used for brickmaking (at the Modney brickyard), burning dirty-white and forming good bricks, but of uneven colour. At a depth of 12 feet, according to the workmen, many stones, said to be limestones, are found; these are very likely septaria,

The remaining notes are by MR. CAMERON:—

"Herringay Hill, close to the Wissey, in Northwold Fen, consists, at the surface, of reddish-brown sandy clay. At the eastern part there was a shallow pit, apparently a trial-hole, and lying about were large flints, septarian nodules (from the Kimeridge Clay), and angular pieces of carstone."

"On the southern side of Methwold Lode, a feeder of the Wissey, there are two hillocks or ridges (one more than a mile long) that have been mapped as Boulder Clay; but in the absence of sections it is difficult to be certain as to their composition. Stones lie scattered about, and are suggestive of Boulder Clay."

Between the Wissey and the Nar.

In the low ground between Fordham and Denver is a mass of Boulder Clay filling a channel, probably of considerable depth except on the west, where it narrows out. As this clay reaches to the Fen-level on the east, and must extend some way beneath the Fen in that direction, it is possible that it may thus continue, in a hidden course, for miles, and may join on to that of the islands in the Fens south of Stoke Ferry, which has been already noticed.

The long shallow cutting on the Stoke Ferry Railway westward of Riston Station (Fordham) is in Boulder Clay. At one spot a little clean clay comes up on the northern side, but this seems to be only part of the Boulder Clay. Further on a little sand, with chalk grains, rises up for a short way, but does not reach the surface. The well at the station is 47 feet deep and is said to be all in clay.

There seems to be a small outcrop of gravel from beneath the clay at the northern edge of the mass, rather more than half a mile north-eastward of Fordham church, and a still smaller one in the re-entering angle on the southern side, about three quarters of a mile N.W. of the same place.

In this district is a long mass of Boulder Clay, stretching perhaps from the eastern margin right across almost to the eastern

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border of the Fens, and possibly indeed, under newer deposits, some way into Marshland. On the east this long strip joins on to the great sheet that spreads far and wide through Norfolk into Suffolk and Essex, to which also the marginal masses in our district, south of the Wissey, also join on eastward, as too do those, yet to be noticed, on the north of the Nar.

There are surface-gaps in the middle part of this long reach; but these are caused by narrow alluvial channels, between Stoke Ferry and Fouldon, beneath which the clay is almost certain to occur, with perhaps one exception, that next westward to Fouldon, where there may be a slight uprise of gravel.

This long spur is of some general interest, as well showing the irregular manner in which the Boulder Clay occurs, cutting across the various older formations, forming cappings to the hills, and sloping down into the bottoms of the valleys. In this last particular indeed we have a fine example of a long channel filled by Drift, to a great extent below the level of the Fens.

It will be convenient to trace the course of this mass from the east, where it joins the great sheet, and to notice its behaviour in its westerly course to the Fens.

The Boulder Clay occurs on the high ground at Swaffham, sending out, however, narrow strips in the small valleys to the north. North-eastward and eastward of that town it also covers the higher ground, with occasional descents to lower levels, and at North Pickenham it reaches right down into the valley of the Wissey, along which it continues southward for a few miles, sometimes, however, not spreading up the left side.

It finally emerges from the valley (as far as this mass is concerned) at Hilborough, and thence extends up to the high grounds of Rowley Corner (W.N.W. of Great Cressingham), Gooderstone Warren and Fouldon Field.

To the east of the last place the Boulder Clay sinks to a lower level, and from Didlington, on the S.E., to beyond South Runcton, on the N.W., there is a long sheet, narrow at first, but broadening from Stoke Ferry onward, with perhaps the very slight interruption above noted, and which, moreover, can be nothing more than a rise of another member of the Glacial Drift. Along the greater part of this route the clay seems to fill a channel, more or less deeply cut in the Chalk, and, on the north, in Lower Greensand also, as well as presumably in the Gault between. At the last the broad mass splits up into various channels, reaching down to about the Fen-level at Holme and to underneath the River Gravel at Tottenhill: most likely indeed the Boulder Clay runs out below the alluvial beds.

Various details of this mass will now be given, following the course taken above, or generally from E. to W.

Mr. Hawkins has furnished the following notes of the northern tract, on the east.

"Between the Nar by West and East Lexham and to beyond the main road E. from Swaffham, there is a large area of Boulder Clay, the Chalk coming up to the surface for a short distance S. of the church at Sporle,

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almost in the midst. There are a great many pits all over this tract, but few give good sections, most having either been turned into ponds or become grown over. Those noticed are perhaps the best and the most accessible, and they are enough to illustrate the general character of the chalky clay of the district."

"In an open pit, on the eastern side of the road, half a mile S. of East Lexham church, Boulder Clay was seen, and again in the bottom of a large pit some ten chains N., beneath gravel. It has also been dug at the fork of the roads at North Street Green."

"A pit on the southern side of the road about three eighths of a mile S. of West Lexham church gave a section of very white clay. There are some large pits 10 chains to the east, on the other side of the road; but these held water. About a third of a mile S.E. Boulder Clay was seen in a pond, close to a mound of gravel, and some 15 chains off (E.N.E.) a large open pit showed Boulder Clay resting on Chalk. The boundary here is rather uncertain."

"The clay may also be seen between two patches of gravel just N.W. of Broomhill Wood."

"In the bottom of the side-valley half a mile E.S.E. of Newton church the clay was seen in a pit."

"Boulder Clay may be seen in the railway-cuttings westward of Little Dunham and of Sporle."

"On the southern side of the high road from Swaffham to Necton, about 3 furlongs E. of the 26th milestone, an open pit showed Boulder Clay overlying chalk. The clay was dug, for brick-making, a quarter of a mile S.W. of Woodgate Pit, and half a mile N.W. of that place was a section showing from 5 to 7 feet of loam and clay, over chalk, which last seems to come to the surface for a short distance here. There seems to be some loam with the clay between this spot and Brick-kiln Farm; but it could not be separately mapped."

"Boulder Clay comes on S. of South Acre, keeping partly to the higher ground, but on the east running down into the side-valley, half a mile W. of the high road, where it divides into two narrow strips, which connect this mass with the large sheet to the east. One of these runs eastward, along the bottom of the valley past Bartholomew Hills, whilst the other runs southward, through Swaffham Plashes. Pits were seen by the side of the road three quarters of a mile S. of South Acre church, at the bottom of the hill a few chains further S., in the bottom of the valley a quarter of a mile and half a mile S.E. of the northern fork of the roads at Bartholomew Hills, and in several places on the strip that runs southward to Swaffham, along which the clay is however hidden by gravel for some way."

"The cutting from Swaffham Station westward gives the following section; chalk being shown only for a short way, as it rises in a sharp curve and then quickly sinks again beneath the overlying deposit":—

Surface soil, to the depth of several feet.
Boulder clay.
Very sandy loam, with small fragments of chalk; of varying thickness. At one place this is interbedded with the re-deposited chalk below.
Chalk, apparently re-deposited, and showing waved bedding.

"Over the greater part of the town of Swaffham the Boulder Clay is overlain by a sandy loam, probably due to the decomposition of the former, and varying much in thickness, judging from the accounts of local informants. A builder stated that he had dug tanks and wells in various parts of the town, and had not found chalk anywhere within about 10 feet from the surface; the top soil being a sandy loam, to the depth of 3½ feet, below which came stiff clay, described as like that in the railway-cutting. Another informant put the depth to chalk at not less than 20 feet, and the thickness of the loam-capping at 5 or 6."

"Some years ago a well was sunk at the Manor House, about a quarter of a mile E. of the church, and is said to have passed through 160 feet of clay."

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"Half a mile N.E. of the church a patch of loam or clay is cut into by the railway."

The tract just southward of Swaffham was mapped by MR. BARROW, who says:—"There are numbers of marl-pits. A little east of the town, where the Watton Railway crosses the high road, the decomposed part of the chalky clay is worked for bricks and pipes, and there is a thickness of about 6 feet of this."

Further south-eastward along the railway (beyond the next road to the south) the cutting shows the Boulder Clay, with a loamy top, and with big flints at the junction of this with the underlying part.

A clay-pit on the northern side of the lane about a third of a mile westward of North Pickenham church showed a mass of flints and sand resting irregularly on, and at one end wedging into, whitish Boulder Clay, and it is to this section probably that MR. BARROW refers as well showing "the origin of the sandy clay, etc. over the Boulder Clay."

The same observer notes that "the large spread of Boulder Clay, from about a mile westward of Great Cressingham, is interesting as showing upon how very even a surface of chalk the clay there rests, for almost every marl-pit shows chalk in place at the bottom."

The following two notes are from MR. CAMERON:—

"At the junction of roads (not on the map) halfway between Grange Farm and Gooderstone Lodge, a thickness of 15 feet of Boulder Clay was seen, with a large hollow of brickearth.

"Hilborough House stands on a knoll (overlooking the Wissey) formed of a boss of Boulder Clay, with a capping of gravel, a remnant probably of a former sheet."

From Didlington to Fouldon the Boulder Clay sinks to below the Alluvium of the Wissey, though the slope on the other side, at Northwold, is bare Chalk. There were no sections of note however.

South of Oxborough the clay is much hidden by sand (? blown), and MR. JUKES-BROWNE notes that a like thing occurs over parts of the larger mass south-westward from that village, especially on the slopes down to the marshes. He says: "Stony loam and clay have been dug at two places by the side of the main road. There are old pits at Oxborough Hithe, about a quarter of a mile north of the Ferry. Marly clay, full of chalk and flints, has been dug at two places near White House, but its surface is covered by blown sand, which varies in thickness from a foot to 5 feet. About a third of a mile N.N.E. of that place is a spring-head, the water of which flows out from reconstructed chalk, beneath 4 or 5 feet of blown sand, the former consisting of lumps of chalk in a matrix of the colour and consistence of putty."

MR. JUKES-BROWNE remarks that "the Boulder Clay east of Boughton evidently fills a wide Pre-Glacial valley, for it passes beneath the turf and alluvium of Barton Fen, and emerging on the eastern side, forms a narrow strip of hummocky ground between the fen and the ridge of Chalk which runs parallel thereto. This Chalk ridge is formed by the hard beds of the *Rhynchonella Cuvieri* zone, and the Boulder Clay appears to be banked against them."

"A shallow pit half a mile north of the ruins of Eastmore chapel showed very chalky clay, full of chalk pebbles, weathering to a yellowish tint and forming a stony soil. About 200 yards N.E. of the chapel was another small pit in what appeared to be reconstructed chalk, the material consisting of hard lumps of chalk in a white marly matrix."

"From the high road between Eastmore and Stoke Ferry the hummocky surface of the Boulder Clay is particularly noticeable as it passes beneath the alluvium."

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Mr. Cameron notes that the Boulder Clay near Stoke Ferry is of the usual kind, clayey rather than calcareous; but that close to the edge of the gravel-ridge, not half a mile north-eastward of Crimplesham church, a pit showed "yellowish-white chalky Boulder Clay, with sandy brickearth intercalated, and with nests of gravel."

Though over the broad tract from Stoke Ferry northward there are few sections of note, there is one of great interest between Shouldham and South Runcton, which Mr. Reid describes as follows:—

"At Fodderstone Gap brickyard the section showed a thickness of 15 feet of dark blue shaly Kimeridge Clay. Fossils are sometimes found; but the only ones seen in the yard were indeterminable fragments of bivalves."

"In the well the clay was 50 feet thick, and it rests on Lower Greensand, from which water rose. Clearly the mass of Kimeridge Clay is a huge boulder, transported from the westward."

Nearly half a mile W. of N. from the brickyard was a pit in whitish sandy Boulder Clay.

On the track about a third of a mile E.S.E. of the ruins of South Runcton Church there is a boulder of shelly sandstone 4½ feet long.

Mr. Reid notes that "an old pit west of Wallington Wood, south-eastward of Tottenhill, gave no section, but there were in it some good-sized boulders, of basalt measuring 1½ × 1 × 1 feet, of fossiliferous Neocomian rock 3 × 2½ × 2½ and 4 × 4 × ?, of earthy limestone 2½ feet in length, and of carstone 2 feet.

It seems likely that the Boulder Clay spreads underground from Tottenhill north-eastward, beneath the gravel and the Nar Valley clay, to the marsh, and then eastward beneath the last, until it joins on to the outcrop at Wormegay, and probably to the patch on the other side of the Nar, just N.E. Of these tracts Mr. Hawkins notes as follows:—

"The narrow strip of fen running up to Tottenhill school, about half a mile north-north-westward of the church, is fringed with Boulder Clay, and on the high road, close to the school, there is a very small patch."

"At Wormegay Boulder Clay occurs over a considerable part of the south-eastern side of the island, and may be seen in the deep drain just below the bridge, in a pit a quarter of a mile W. of the church, by the side of the lane that crosses the fen (to Shouldham Warren) and in a pond on the northern side of Park Farm."

Of the isolated patches in this tract there is little to be said, as they are mostly small and without clear sections.

Mr. Jukes-Browne notes that "on the hill south of Gooderstone there is marly clay and gravel, which have been dug for many years at the pits about a quarter of a mile S. of the church. These show some depth of coarse gravel, chiefly composed of hard chalk and flint pebbles, overlain by a varying thickness of compact yellowish sandy marl. In the only face open (1886) this brickearth thickened westward, from 0 to 8 feet, and seemed to be without stones; but boulders of basalt and of other rocks lay on the floor of the pit. A smaller pit had been opened in light-buff marl on the southern side of the large pits. The gravel comes to the surface only here and there, and could not be separately mapped.

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Of the clay north of the stream, which probably joins on to that on the south, beneath the marsh, Mr. Barrow says that it is of interest from the fact of the occurrence, in the pits, of large slabs of very fossiliferous brown sandstone, presumably Neocomian.

Mr. Hawkins contributes the following notes:—

"In the patch reaching from Great Friars Thorns (W.N.W. of Swaffham) north-eastward, many pits have been dug."

"The clay has also been dug in the patch half a mile S.W. of West Acre Mill, and it may perhaps extend further north than is shown on the map. There is a large pit on the western side of the wood, and a smaller one inside the wood, at its southern end, but both were filled with water."

"Many pits have been dug in the larger patch to the east, but they were either overgrown or full of water."

North of the Nar.

It will be convenient firstly to notice the Boulder Clay in the Greensand tract, on the west, and then that over the Chalk. We find there that the deposit occurs both as a capping to the hills, and as a lining to the valleys, the high ground about North Runcton and Middleton being the largest example of the former, whilst the latter is well seen along the bottoms of both the Middleton and the Bawsey Valleys, in the lower parts of which the Alluvium is more or less bordered by Boulder Clay on both sides, which are probably parts of one trough of Drift.

On the right bank of the Nar, at the northern side of Setchy Common, a small patch of Boulder Clay just touches the Alluvium, and at West Winch this clay also reaches low down the slope bordering the Fens.

At Middleton a pit a quarter of a mile north-westward of the church, and on the western side of the road, showed whitish Boulder Clay.

As before-noted the small outcrop by the marsh, about a mile S.W. of Bilney Lodge, may join on underground to the mass at Wormegay (see p. 63).

On the Eastern and Midland Railway, about a third of a mile south-eastward of Hardwick, there is a very short slight cut in Boulder Clay.

A short tongue of Boulder Clay seems to reach up northward, from the strip that skirts the marsh, to the southern side of the railway-cutting just S.E. of the ruined church of Mintlyn. The clay may be seen in the cutting on the other railway, at a much lower level, about two-thirds of a mile south-south-eastward of the same place.

About a third of a mile S.E. of the ruin an old pit was clear only at the part close to the cross-roads, where sand (Lower Greensand) was seen, with a hollow filled by dark Boulder Clay, weathered upward into loam, and with sandy and gravelly soil. Possibly the clay may extend further than the boundary of the wee patch mapped here, as beeches grow to the east, and those trees are lovers of a calcareous soil.

At the eastern end of the strip skirting the River Gravel eastward of Middleton Station, a pit showed the Boulder Clay abutting sharply against the Lower Greensand on the north.

The most interesting section of the district was in a high-level mass at Bawsey Brickyard, on the slope of Leziate Warren, south-westward of Chilvey House, where, in 1881 and 1883, the pit gave good examples of the peculiar behaviour of Boulder Clay, as illustrated in Figs. 14 and 15, which are reproductions of sketches made in the highest part of the pit.

The sandy soil here masks the clay, varies up to 5 feet in depth, and gives the whole hill-top the appearance of being bare Lower Greensand, an illusion soon dispelled however on sinking shallow holes.

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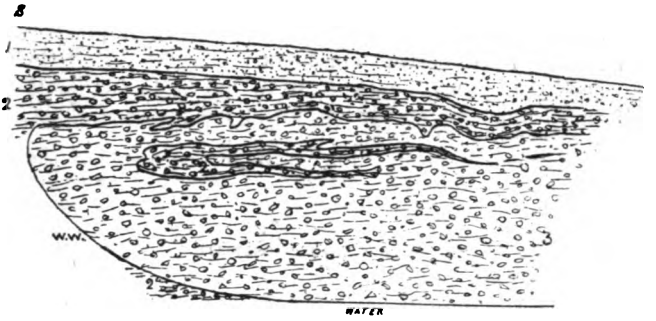
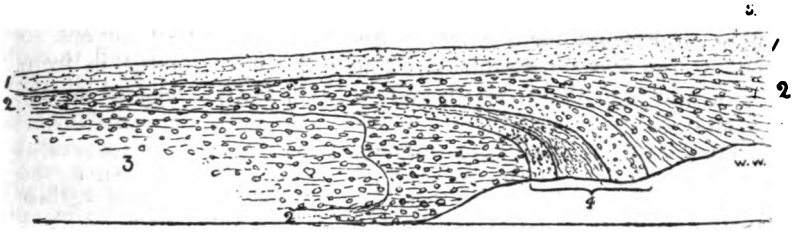
FIGS. 14, 15. *Parts of the Section seen at Bawsey Brickyard in* 1883.

On the Western Face.



On the Eastern Face.



1. Sandy soil.

Boulder Clay.
2. Grey Boulder Clay (dark on the eastern face, where only was there much seen), weathering brown at top.
3. Whitish Boulder Clay.
4. Sandy and gravelly beds (on eastern face) apparently in the Boulder Clay.

The junctions of the dark and light-coloured Boulder Clays are sharp. The dark grey, which is chiefly very dark, and has been worked to a depth of 10 feet or more, seems to go right under the whitish, besides capping and penetrating it. The difference is not one brought about by decalcification, the dark clay containing chalk, and the two varying much in relative position. The dark clay also contains slabs of shaly Kimeridge Clay and a variety of rocks.

Lower down, northward, grey sandy clay with a ferruginous layer (the middle clayey division of the Lower Greensand) was seen, on the eastern face, coming out from beneath the Boulder Clay, and was at first mistaken for Drift. Then, on the western face, sand was seen beneath the former clay, of which only a thickness of 3 feet was noted.

Just west of the pit, at the edge of a fir-plantation, is a small old pit in chalky gravel, and there are signs that this gravel may continue (in patches?) south-westward along the edge of the Boulder Clay. On the other hand it may perhaps represent the gravelly bed in the Boulder Clay at the brickyard.

By the small patch of gravel a little eastward of the large pits, Boulder Clay was again seen, capped by sandy soil.

This place is worthy of the attention of observers, as the sections are likely to vary, from the cutting-back of the pits for the brickyard.

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The two parts that were clear, in 1883, in an old pit less than a quarter of a mile southward of Ash Wicken church, showed the following succession :—

Brown stony soil and grey Boulder Clay; ? to 4 feet.
Light-buff Boulder Clay, with large flints, etc. At the clearest part with a roughly horizontal layer of buff sand from 6 to 9 inches thick, and seen for a length of 17 feet (without the end being seen); 4 or 5 feet.
Grey Boulder Clay; seen to 3 or 4 feet.

The pit higher up, N.W., seemed to be in light-coloured Boulder Clay, a little of this being seen at the top, with a few pieces of chalk; but all the rest was overgrown.

Boulder Clay was seen in the ditch on the northern side of the railway seven eighths of a mile north-eastward of Gaywood church. Riffley Spring, a little further in that direction, may rise from a sandy bed in the clay.

At Pot Row, the hamlet over a mile westward of Grimston, clay was turned out from a well.

We pass now to the Chalk-tract, in which the Boulder Clay occurs chiefly on the higher ground, the large mass on the east joining on, beyond our district, to the great sheet that covers so much of the Eastern Counties. The following account is from the notes of MR. WOODWARD and of MR. HAWKINS, and firstly the latter :—

"Half a mile or so southward of Gaytonthorpe church there are several pits on the top of the hill, in one of which Boulder Clay was seen to the depth of 12 feet, whilst in another the clay was shown lying against gravel."

"A large pit half a mile W. of West Acre was overgrown with trees, except at the eastern end, where Boulder Clay was seen, beneath gravel and sand."

"Over the north-eastern part of Walton Field and the greater part of West Acre Field there is a spread of Boulder Clay, the boundary of which was very difficult to determine. On the eastern side of the farm-track from West Acre to Gaytonthorpe, and over a mile from the former, a pit showed sandy loam over clay, which latter seemed free from chalk. East of this, and close to a small square copse less than a mile N.N.W. of West Acre church, another pit gave the following section" :—

Chalky Boulder Clay; about 6 feet.
Brown sand and gravel, bedded, with flints, carstone, and many fragments of Kimeridge shale; 3 feet.
Clayey sand, quickly passing down into stiff grey clay; a foot.
Buff sand, with Kimeridge Clay; 2 feet.
Chalky Boulder Clay, with Kimeridge Clay; to 3 feet.

"The middle three beds showed no sharp planes of division."

"There are many other pits showing Boulder Clay in the area under notice, and many of these go down to the Chalk. This junction was seen in a pit on the northern side of some farm buildings a mile westward of High House; another pit rather more than a quarter of a mile S.W. of the farm-house being in sandy Boulder Clay. Chalky Boulder Clay may be seen at the cross-roads near the farm-buildings belonging to High House."

"There is bluish Boulder Clay in a pond by the side of the road over three quarters of a mile S.W. of High House."

"A mile N.E. of West Acre church a pit, low down in the valley, showed Boulder Clay containing Kimeridge shale. The wood a little westward may also be on a patch of the clay, though the soil is sandy."

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"Rather more than a quarter of a mile S.E. of the 32nd milestone, on the high road eastward of Gaytonthorpe, a pit showed 7 feet of Boulder Clay over Chalk. The extent of the clay here is doubtful."

"Further eastward, on the southern side of Massingham Heath, there is Boulder Clay close to the 31st milestone, with a pit in it, and there was once a brickyard. Here, too, the boundary is doubtful."

"The greater part of the village of Castle Acre, N. of the main street, lies on Boulder Clay, which spreads for nearly a mile westward. The clay not only forms the higher ground, but slopes down the valley, to the Alluvium. Sandy loam and Boulder Clay were seen in a shallow pit about 8 chains S. of a farm-house (not marked on the old map) on the road to West Acre, three quarters of a mile W. of the Peddar Way. Half a mile N.W. of the church some marly sand and Boulder Clay may be seen along the edge of an old overgrown pit. A little less than a quarter of a mile W. of the church a pit in a brickyard showed a bed of sand interbedded with the Boulder Clay, and this may be traced on both sides of the valley. On the eastern side of the Peddar Way, close to where the road to West Acre branches off, clay, without any chalk in it, may be seen round a pond, near an old barn."

"There is Boulder Clay in the valley about three quarters of a mile S. of Emanuel Farm, and there is another small exposure at the edge of the marsh about a mile E.N.E. of Castle Acre church."

"At Castle Acre Wicken there is some Boulder Clay, with a very doubtful boundary, which may join on to a smaller patch on the Peddar Way, just E."

"S. of Castle Acre Wicken there is a larger outlier. On the eastern side of the Peddar Way a thickness of 10 feet of Boulder Clay was seen in a pit, and about a quarter of a mile westward of that road a large pit, behind a farm-house, showed chalky Boulder Clay to the depth of 12 feet. Another pit, a third of a mile S.W., showed the junction with the Chalk."

"At the south-eastern corner of Grimston Heath, W. of the Peddar Way, there is a patch of Boulder Clay in which several pits have been dug, one of which showed 5 feet of the clay over chalk."

Writing of the Nar Valley generally Mr. Hawkins says:—"Putting aside the question of the age of the gravels on either bank of the stream, it would seem that the Nar, above Narford at all events, runs in a channel which existed in Pre-glacial [or Glacial] times, that is before the deposition of the Boulder Clay. For it will be noticed, on looking at the map, that the Boulder Clay runs down to the Alluvium W. of Castle Acre; whilst there seems also to be a little in a like position on the east (just N. of Newton). Should the clay in the old brickyard E. of West Acre Mill, and that on the other side of the river, turn out to be Boulder Clay (it has been coloured as brickearth), this would give additional evidence in the same direction. Much further down the valley, close indeed to its mouth, Boulder Clay occurs at the level of the Fen, both at the eastern end of Wormegay and N.E. of Tottenhill" (see p. 63).

We come now to the large mass from the Peddar Way over Rougham, the Weasenhams, and the Lexhams, which is a spur of the great sheet.

Mr. Hawkins says that "on the eastern side of the Peddar Way for some distance both N. and S. of the high road the soil is sandy and obscures the boundary-line of the clay; but a pond at the eastern side of Massingham Heath showed sandy clay, to the depth of 4 feet. On the eastern side of the Peddar Way, nearly three furlongs southward from the 30th milestone on the main road, a pit showed 4 feet of loamy sand, with flints, over Boulder Clay."

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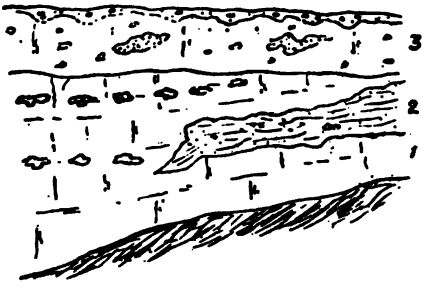
The following notes of this tract are contributed by MR. WOODWARD:—

"About 3 furlongs S.E. of Washpit Farm, W.S.W. of Rougham, a pit gave the section drawn in Fig. 16, notable for the wedge-shaped mass of clay and sand in the Chalk. The flint layers in the latter did not seem to be broken up or disturbed; so that the clay and sand probably fill an irregular pipe, made by the dissolution of the Chalk."

FIG. 16. *Section in a Pit near Washpit Farm south-westward of Rougham.*



3. Gravelly soil, over Boulder Clay with nests of sand.
2. Brown clay and sand, with flints, up to 3 feet.
1. Chalk, with flints. Talus at the foot.

In the pit S.E. of Emanuel Farm, N.N.E. of Castle Acre, where the Boulder Clay may be seen resting on the Chalk, the latter has a blocky and knobby form, to the depth of 5 or 6 feet, while the flints are somewhat irregular. This is clearly due to surface-disturbance and weathering."

"N.W. of Crowhall Farm, northward of West Lexham, a well-marked layer of flints proves the Chalk to have been bent into a gentle anticlinal. Above the Chalk is an irregular bed of Boulder Clay, and above that gravel, which is thin and irregular, but thickens southward."

"At High Grove, some two thirds of a mile north-eastward of Rougham, the clay-land is heavier than it is, as a rule, southward of that village."

In the Fens, west of the Ouse.

Of the islands in this tract six consist more or less of Boulder Clay, and at two of these, Manea and Pye Moor, no other formation seems to occur at the surface; whilst at a third, Stonea, it is hidden only by a small patch of gravel, and at a fourth, Butcher's Hill, by a larger patch. In the other two, Littleport and March, which are larger, the clay occurs over the higher ground and also sweeps down to below the bordering marshes. In all six therefore the Boulder Clay spreads from the islands into the great Fen-level; but how far it extends under the Fens is uncertain: possibly all these island-masses may be connected underground, and form one long channel.

The following details of one island, by MR. SKERTCHLY, are taken from the Fenland Memoir, with some slight alteration.

To the N.W. of Littleport some small elevations occur (some of which are only large enough to support a farmstead), whose composition is somewhat peculiar.

One of these extends from Grub's Farm to Butcher's Hill near the Bedford River. It abuts upon the silts of the old Ouse, and its most

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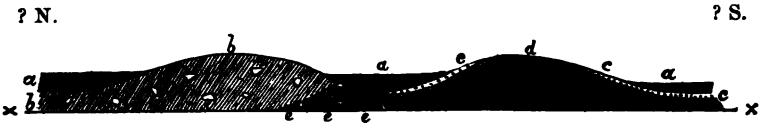
complicated section is shown in Fig. 17. The greatest height of the section is about 15 feet, the length a quarter of a mile, so that the drawing is distorted. The section cuts two small spurs, between which peat is seen, the main mass of peat showing outside. At *b* the island is composed of a mass of sandy and gravelly clay, containing many angular flints, large striated septaria, and chalk boulders. At *d* the Kimeridge Clay takes the ground, and is flanked by a thin bed of sand, *c c*.

The general section across the island is shown in Fig. 18, which follows the line of road by Butcher's Hill.

The silt *b* is fen clay, and a portion of the Old Ouse deposit; hence this part of the island stood within the channel. The peat is seen underlying the silt, and cropping out from beneath it on the S.W. The silt is banked up against the island, which is flanked with sands and gravels. These lie upon a worn surface of Boulder Clay, and this again upon a worn surface of the Kimeridge Clay.

FIGS. 17, 18. *Sections across Butcher's Hill Island.*

Along Road between Butcher's Hill and Grub's Farm.



a. Peat.
b. Boulder Clay.
c. Sand.
d. Kimeridge Clay.
e. Layer of Septaria.
× × Water-level.

Across Butcher's Hill.

a. Peat.
b. Silt.
c. Sand and gravel.
d. Boulder Clay.
e. Kimeridge Clay.
× × Water-level.

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CHAPTER 9. GLACIAL DRIFT, ETC.

Beds above the Boulder Clay.

Difficulties of Classification, etc.

The difficulty in classifying many of the patches of gravel that occur over some of the higher parts of our district has been already alluded to (pp. 45, 46, 54, 55), and it must be understood therefore that, in describing together the following set of deposits, we by no means imply that all are of the same age, or even that the Glacial age of all is assured. These beds have to be described somewhere, and whilst they are newer than the Boulder Clay, they seem to be older than the River Gravels and other deposits which can be classed as Post-Glacial. As a a matter of convenience, then, they are grouped together, and are classed with the Glacial Drift, from having a more apparent alliance thereto than to anything else.

In the group now to be described are contained representatives of perhaps the Ancient River Gravels of Mr. Jukes-Browne, of the Flood Gravel of Mr. Skertchly, perhaps of the Cannon Shot Gravel of Mr. Wood, and of the Esker Drift, which occurs in the north-eastern part of the district. Whether these divisions are more than local, and whether they may not be different conditions of deposits that were being formed more or less together in time, though apart in place, with other suggestions of like character, are questions that cannot be answered here, but depend on considerations ranging beyond the district with which we are concerned.

We make no dogmatic assertion, and geologists should be thankful for this and for the consequent freedom to enjoy their own opinions in peace. The facts of the occurrence and of the behaviour of the various gravels are not in the least affected by the classificatory doubts, which need not trouble the purely practical man.

We may again, then, adhere to a topographical arrangement in describing the beds with which we are now concerned, some of which might well be classed as *Beds of Doubtful Age*. But before doing this it may be well to refer to the subject of Eskers, a form of Drift not noticed in southern England before the Geological Survey work in Norfolk was well advanced, when Mr. H. B. Woodward and myself independently came to the conclusion that we had met with it. A general account of the subject, and a comparison of our eskers in western Norfolk with others in Cumberland has been given by our former colleague Mr. T. V. Holmes, from whose paper the following remarks are taken.*

* *Geol. Mag.*, dec. ii., vol. x. pp. 438–445. (1883.) Reprinted in *Proc. Norwich Geol. Soc.*, pt. viii. pp. 263–272, with discussion. (1884.)

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"Eskers may be defined as ridges and mounds of gravel and sand which owe their existence and, in the main, their shape, to their having been heaped up by the action of water in the positions in which they are now seen. Of course they often owe something to circumdenudation, but a good section across an esker ridge contrasts in the most striking way with one across a mere gravel outlier. For whereas the latter would show nearly horizontal bedding, or a slight tendency to a basin shape, an esker has evidently been heaped up as a bay or sandbank is heaped up at the mouth of a river, the beds having a general dip from the centre towards the sides. . ."

"Perhaps the most striking peculiarity of eskers is their irregular and unaccountable distribution," either as forming the highest ground or in valleys.

"British eskers are most common in districts abounding with ordinary Glacial Drift, and appear to date from about the close of the Glacial Period."

He concludes that the phenomena seem "to be explainable only on the supposition that eskers result from the irregular heaping up of material in shallow seas or estuaries from the action of diverse currents." In the discussion MR. WOODWARD noticed PROF. J. GEIKIE'S view that eskers "had been heaped up principally by the action of subglacial waters during the final melting of the confluent glaciers," and said that "He was disposed to adopt this view in a measure, and to regard the Eskers as the last relics of the great ice age in the district, and as formed by the floods and torrents that attended its passing away."

MR. WOODWARD writes (July, 1893): "Since these remarks were made I have seen eskers, in Scotland, that may have been formed by Glacial ice passing over gravel-flats and ridging up parts of the gravel. Such an explanation might apply to some of the Norfolk eskers, but without re-examining the district it is hazardous to say more than to make the suggestion."

South of the Wissey.

The patches of gravel on the higher grounds that reach from Gravel Hill, S.W. of Brandon, along a line northward to Whillington, near Stoke Ferry, seem, at first at all events, to be allied to the Ancient River Series of the tract to the south, and MR. SKERTCHLY remarks that "around Brandon these gravels are readily distinguishable by reason of the large amount of foreign material that they contain. They consist, to the amount of about half, of rounded and subangular pieces of Coal Measure sandstone, of Millstone Grit, and of a few of quartz. Some of the first have been worked into implements, which are the so-called quartzite implements described by SIR J. EVANS."*

In this, however, he seems to be mistaken, as other observers notice the occurrence of quartzite and of implements made therefrom.

* Ancient Stone Implements, p. 510. (1872.)

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"These gravels can be well studied at Gravel Hill, nearly two miles S.W. of Brandon," a place that has a short literature of its own, from the occurrence of stone implements.

Mr. J. W. Flower first described the spot* (1869), as "91 feet above the river, and . . it [the gravel] comprises an area of from thirty to forty acres, occupying the summit of a hill overlooking an extensive sandy plain, which at a short distance merges in the great level of the fens. The bed of gravel here is usually not more than 10 feet in thickness, and often less . . the implements are usually found at the bottom of it, and occasionally they lie upon the chalk . ."

"By far the larger proportion . . consists of rounded quartzites, and a few jasper pebbles . . In some spots, indeed, these pebbles form a compact mass with hardly a single flint . . while many [of the implements] are of very coarse workmanship, and much worn and broken, others are of excellent forms, and as sharp and fresh as when first made."

In his great work of 1872† Sir J. Evans gives some further particulars, with descriptions of implements.. He adds to the stones of the gravel "clay-slate, quartz, greenstone, and limestone," and thinks that all the foreign stones were "derived from Glacial beds, from which also many of the flints appear to have come. The matrix is of coarse red sand, and there is usually some thickness of sand above the gravel." He thinks that Mr. Flower's estimate of the amount of pebbles of quartzite, etc. is "very far in excess," and then says, "Flint implements have been found here in considerable numbers—at all events, many hundreds. . . They appear to occur at all depths." Further on he remarks that "Flakes and spalls of flint are abundant," and that "One of the most interesting features at Gravel Hill is that there, for the first time, were found cutting stone implements of the Palæolithic Period formed of other materials than flint or chert," one of felstone being specially alluded to (see *post*, pp. 112, 117).

Mr. T. Belt published a short note of this spot, but without adding any further fact to those above given.‡

It should be noted that Sir J. Evans classes this gravel as Post-Glacial, as a high terrace of River Gravel; an opinion in which he will be joined by many geologists, perhaps by most. My own opinion inclines that way, and it is merely as a matter of convenience that this somewhat doubtful patch is described under the present heading.

Of the larger patch to the N.W. Mr. Skertchly says, "Northward of Brick Kiln Farm gravel was dug largely in 1875, to the depth of 7 feet. It consists of large stones in a light-coloured calcareous sand, the upper 2 feet stained red. The stones were mostly flints, weathered brown and rounded, with many unweathered; but pebbles of Coal Measure sandstone, of quartz, and of hard chalk abounded, and there were some pieces of dark ironstone. The gravel-pit near the western end of the wood was filled in (1875); but a heap of the material from it was seen to be of much the same character as that of the above."

The following notes of gravel at Methwold are by Mr. Jukes-Browne:—

"There is a small outlying patch of gravel about a mile and a quarter S.W. of Methwold, the pit in the plantation exposing 10 feet of loose gravel, consisting entirely of small pebbles of hard chalk. This has been dug extensively, and is used for mending the roads, either alone or mixed with broken flints." There are also flints and some small phosphatic nodules in this gravel, which is current-bedded eastward. At the eastern end of the pit there was sand.

"Gravel has been dug all round Methwold Lodge, and pits were open in 1886 in the field about a quarter of a mile N.W. of the house. The gravel, which has a decidedly Glacial aspect and greatly resembles the Plateau gravels of the Gog Magog Hills, consists chiefly of flints and pebbles of hard chalk, besides which large lumps of septaria (? from the Kimeridge Clay), pebbles of quartzite, carstone, and Red Chalk were frequent."

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* *Quart. Journ. Geol. Soc.*, vol. xxv. pp. 449. 450. (1869.)

† The Ancient Stone Implements . . of Great Britain, 8°, *Lond.*, pp. 507–511.

‡ *Nature*, vol. xvi., no. 397, p. 101. (1877.)

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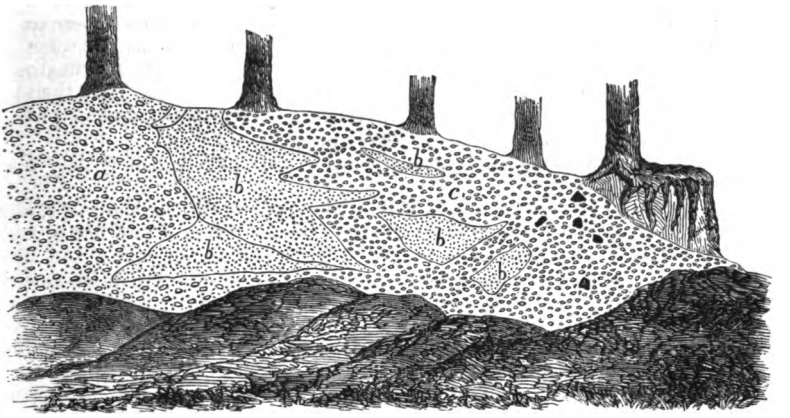
Another pit in similar gravel had been recently opened by the roadside three quarters of a mile S.E. of Methwold church, and the gravel appears to extend continuously from this place to the village."

"At the large chalk-pit in Methwold, west of the windmill, a thickness of about 12 feet of stratified gravel and sand is shown in the western face of the pit, but at the northern corner there is not more than 4 feet of gravel and gravelly soil."

The next note, by MR. SKERRCHLY, is taken from the Fenland Memoir.

At White House, N.W. of Methwold, the gravel again comes on and forms a bank on the edge of the fen. It is full of flints, some of which are very large and irregular, and in its upper portion shows no trace of bedding. The material is generally finer below and contorted, but the whole section is very irregular. Fig. 19 shows one face of the pit:—

FIG. 19. *Section in a Gravel Pit at White House, near Methwold.*



a. Sand and gravel indiscriminately mixed.
b. Sand. *c*. Gravel.

At a later date I saw on the western side of an old pit (S.S.W. of the house) a mass of chalk-marl and stones, perhaps a kind of Boulder Clay, in the sand and gravel.

Between the Wissey and the Nar.

Westward and north-westward of Downham Market are some small patches, of the most southerly and most northerly of which MR. REID has made the following notes:—

"A pit half a mile W.N.W. of Muzzle Farm (West Dereham), showed 10 feet of gravelly chalky current-bedded sand, full of *Belemnites*, teeth of *Pycnodus*, etc."

"A quarter of a mile S. of Fodderstone Gap, a thickness of 20 feet of sandy gravel was seen in a pit."

Of the Wereham, etc., gravel, MR. CAMERON writes as follows:—

"A ridge, broken only in two places, ranges along the high road from Crimplesham to Stoke Ferry, with many pits on either side, the gravel being much worked, chiefly for road-material. The greatest thickness of the deposit cannot be much under 40 feet, the pits being dug sometimes to the depth of 25 feet, while,

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at the Crimplesham end the workmen made trial-holes to 20 feet below the floor of a pit and reported gravel with alternations of sand, ending in white sand, which was not pierced."

"Bones have been found 10 feet down in the gravel, and derived reptilian bones, from the Oxford and Kimeridge Clays, occur throughout."

"Whilst in places this gravel rests on Chalk, in others it seems to rest on Boulder Clay, and in one pit a little Boulder Clay was seen over it, suggesting that the gravel may be both overlain and underlain by such clay."

The occurrence of a little Boulder Clay on the Chalk in the chalk-pit N.N.E. of West Dereham Church has been already noted (pp. 32, 33). MR. CAMERON says that this clay thickens north-westward and separates the gravel and the Chalk.

Of the large pit on the western side of the road just N.W. of Wereham, MR. JUKES-BROWNE writes that, "the section showed coarse gravel, overlain by bedded and current-bedded sand, the laminæ inclining at various angles, but with a uniform direction from N.W. to S.E. To imagine a river running in that direction, *from* the Fenland to the higher ground, seems out of the question, and it is more likely that the gravel is a beach-deposit, formed during emergence from the sea of the great Glacial submergence."

In this pit many very old graves occurred, and old British pottery was found in some cases.

A pit on the northern side of the high road a little north-westward of Stoke Ferry, showed, according to MR. CAMERON'S notes, "from 4 to 6 feet of stiff unstratified clay, with chalk and scratched flints, resting on coarse and fine flinty gravel," and in the adjoining field I saw, when with him in 1883, very glacial-looking material, consisting of coarse irregular unstratified loamy clay, full of stones, over the gravel. MR. CAMERON notes that the clay was from 15 to 18 feet thick, and that some of the gravel was very coarse, with large rounded flints and pieces of carstone, clearly like the Cannon-shot gravel of other parts. He also noted in this gravel the occurrence of pieces of various igneous, Carboniferous and Jurassic rocks, of large quartzite pebbles, of Chalk and Red Chalk, of coprolites and of Lias, with *Ammonites* and *Gryphæa*.

Passing eastward from Stoke Ferry, MR. REID notes that "a pit at the cross-roads, a mile E.N.E. of Fouldon church, showed a thickness of 15 feet of gravelly and chalky false-bedded sand, chalk coming up in the middle of the pit, rising to the south. A boulder of Neocomian grit, 4 × 3 × 1½ feet in size, was seen loose in the pit." The chalk, when seen by me somewhat later, seemed to be of a reconstructed kind.

On Gooderstone Warren MR. CAMERON saw a pit by the roadside, a quarter of a mile S.S.W. of Gooderstone Lodge, giving the following section:—

Rather coarse clayey bedded gravel, with layers of clay, the component stones being flint, chalk and quartzite; 10 feet.
Boulder Clay.
Chalk.

This patch of gravel was accidentally omitted from the map for some time.

Of the patch at North Pickenham MR. BARROW remarks that it is "Cannon-shot gravel, consisting of very much rounded flints, and, as it rests on the Chalk, there is no proof of its exact age."

We now come to the tract northward of Swaffham, where there are many small patches of gravel, chiefly in the valley of the Nar or of some tributary, some of interest from their esker-like form, as they make well-marked ridges, though broken at intervals (Bartholomew Hills).

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Mr. Rose tells us of "part of a tooth of *Mastodon latidens?* found in a gravel-pit at Swaffham";* but he does not give the precise spot, and the specimen seems to have been lost, as Mr. J. Reeve, of the Norwich Museum, writes (1881) that it did not go to that museum, with most of Mr. Rose's collection. Mr. J. Gunn remembered that there was such a tooth however, but Mr. Woodward remarks that it must have been derived from Crag.

The following details are from Mr. Hawkins' notes:—

"Gravel has been dug to a considerable extent on both sides of the high road a little more than half a mile north of Swaffham Railway Station, and an open pit showed 4 feet of loose sandy gravel, consisting mostly of angular and subangular flints and flint pebbles, but there were also pebbles of quartz and of quartzite, besides a few fragments of old rocks."

"At Narford River Gravel seems to come on over beds of an older series; a rather irregular deposit of sand and gravel, which one was obliged to include within the same boundary eastward to South Acre, though it contracts to a very narrow strip about a quarter of a mile south-eastward of West Acre Mill."

"About three eighths of a mile north-eastward of Narford Hall and an eighth of a mile from the road, some pits showed 7 or 8 feet of sand, irregularly interbedded with flint gravel, which contained a few fragments of carstone. The flints were mostly angular, a good many being large and unbroken and not appearing waterworn. One pit, a little apart from the rest, showed sand alone, and this was loamy toward the bottom of the pit. A few fragments of rude pottery, probably British, were found in the soil."

"Further eastward, by the row of cottages shown on the map, on the northern side of the road, a shallow pit again showed sand, to the depth of 3 feet, beneath a flinty soil."

"Still further eastward, by the side of the road S.E. of West Acre Mill, and below the ruins of the old chapel, some excavations showed gravel and buff sand, bedded, with layers of small rounded pieces of chalk."

At a higher level, to the south and south-east, are some patches along a slightly curved line for about 3 miles, and in places, especially at Bartholomew Hills, these take an esker-form. The mapping points to their all forming parts of one set, partly on the flank of the Valley of the Nar and partly in the bottom of a tributary-valley. Their description again is from Mr. Hawkins' notes.

"On the high ground about half a mile S.S.E. of West Acre Mill a pit showed 7 feet of brown sandy gravel, indistinctly bedded, and consisting of angular and subangular flints, with some flint pebbles, and a few quartz pebbles and fragments of hard micaceous sandstone. The two patches further westward have marked features."

"From the by-road south of South Acre nearly to the high road on the east gravel comes on along the side of the little valley, and at the western side of the high road are two small patches. On the other side of the high road a large mound of gravel occurs in the fork of this road and that to Great Palgrave, but no clear section was to be seen."

"On the north-eastern side of the latter road is a well-marked mass, in which two pits showed the gravel to be about 25 feet thick. In one it was finely bedded horizontally, with layers of sand: in the other it was more coarsely bedded in waved layers, one bed, near the top, being cemented, by iron-oxide, into a hard stone. The materials of the gravel here are angular and subangular flints, a few pebbles of flint and of quartz, and fragments of carstone, of chalk, and of Kimeridge shale, which last I have not noticed anywhere to the east."

"Two other patches, S.W. and S. of Little Palgrave, complete this line of gravel."

* *Phil. Mag.*, ser. 3, vol. viii. p. 30. (1836.)

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The amount of linear arrangement of the small patches in the two tributary valleys eastward of Newton is again notable. These, too, are described by MR. HAWKINS.

"About a quarter of a mile S. of Dunham Farm a pit showed 8 feet of very sandy gravel, with fragments of chalk."

"At Winchester Hills, eastward of Newton, a pit on the southern side of the road showed about 12 feet of gravel; the upper part coarse, unstratified, and containing many large unworn flints, besides carstone and quartz pebbles; the lower part bedded and with layers of sand. At one place the sand was very chalky and there were large bits of chalk in the gravel."

"In the larger valley to the east, which starts at Little Dunham, there are two low mounds, three quarters of a mile S. of Tulip Hill, in one of which was a pit about 12 feet deep in very coarse gravel, with many large flints and some fragments of carstone, the bedding being indistinct, except in one place near the bottom."

"At Tulip Hill are two large mounds (mapped together) and two smaller, on the eastern side of the valley and extending up the slope. The sections seen proved the gravel to be about 25 feet thick. It is rather fine and distinctly bedded, contains layers of sand (which often show current-bedding on a very small scale), consists of angular and subangular flints with a few quartz pebbles and rounded pieces of soft decomposed chalk, and presents a marked contrast to that on Winchester Hills," only a mile to the west.

"At East Lexham there is a mass of gravel and sand, resting partly on the Boulder Clay and partly on the Chalk, and stretching from the Alluvium southward up the sloping ground. The following sections illustrate the varying nature of the deposit."

"In the brickyard about a quarter of a mile S.W. of the church the section was":—

Sand, with layers of fine flint gravel; 7 feet.
Fine brown loam; to 1½ feet.

"Sand has also been dug in a small pit about an eighth of a mile W., but gravel occurs on the higher ground S."

"About a quarter of a mile S.E. of the brickyard, and near the road to Little Dunham, is an old overgrown pit, apparently in coarse gravel, with Boulder Clay shown at the bottom."

"About half a mile S.E. of the church, and close to the south-western corner of Lexham Plantation, a shallower pit showed about 6 feet of brown sand, containing a little flinty grit in places."

Perhaps some of the patches in the bottom of this side of the valley of the Nar may join on, beneath the Alluvium, to others on the northern side.

North of the Nar.

It will be convenient to notice firstly the gravel along the valley of the Nar, mapped by MR. HAWKINS, and, in the far east, by MR. WOODWARD, whose notes will now be used.

MR. HAWKINS says of the gravel at West Acre that it "runs down to the marsh, and is probably Glacial," there being no certain evidence, the same being the case also with the neighbouring patches north-westward and east-north-eastward. "The gravel and sand seen in the pit half a mile westward of the village seems to extend some way along the top of the hill and to overlap the Boulder Clay."

"In the bend of the river between West Acre and Castle Acre there is a good deal of gravel, on the slope of the hill and running down to the marsh. Three quarters of a mile east of West Acre church this is cut through by a small valley, the lower part of which is filled by a narrow strip of clay, which seems to be free from chalk, and may be seen in a pond 7 chains south of the road from one village to the other. This clay may be of the same age as that in the old brickyard on the other side of the river. A shallow pit by the roadside a quarter of a mile N.E. of West Acre Mill showed a foot of sandy gravel above 3 feet of sand."

"From Castle Acre eastward to opposite Newton Mill gravel and sand again occur. Gravel has been dug at Castle Acre, near the smithy, on the

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southern side of the road to Newton, and also close to the marsh a little southward, where there may also be some River Gravel. In the side-valley there is clay."

MR. WOODWARD says that "at Burrow Hills, West Lexham, and in the valley to the west, the gravel-hills have esker-like forms. The western slope of Burrow Hills is a very sharp and fairly straight escarpment, looking like a great artificial earthwork." I have heard of such ridges having elsewhere been mistaken by antiquaries for earthworks.

MR. HAWKINS noticed "a section, on the northern side of the stream, a quarter of a mile S.E. of East Lexham church, which showed from 8 to 10 feet of coarse, and in places very sandy, gravel, with an indistinct plane of bedding about halfway down, and composed almost entirely of flints (some large and unworn), with a few fragments or nodules of carstone, and a grey wether-sandstone."

Turning now to the patches of gravel, etc. southward from the Gaytonthorpe Valley, and the continuation of its line eastward, the notes of MR. HAWKINS and of MR. WOODWARD are again under contribution.

The former observer says that "at the eastern end of the large gravel-pit three quarters of a mile southward of Gaytonthorpe the gravel was seen lying against Boulder Clay;" but I have also a note of what seemed to be a little whitish Boulder Clay overlying chalky gravel; so that perhaps this patch, or part of it, may belong to the beds beneath the Boulder Clay. MR. HAWKINS says that "further east there are other pits, inside the wood, but shallow and overgrown."

Of the patch half a mile and more eastward he remarks:—"Nearly a mile S.E. of Gaytonthorpe church was a pit showing a thickness of about 12 feet of gravel and sand. The gravel is composed of flint pebbles, with angular and sub-angular flints (many large and waterworn), pebbles and partly worn fragments of chalk, and fragments of carstone and of various old rocks, the carstone often in the form of nodules that look like solid pebbles, but which, on being broken, are found to contain ochreous sand. Except for containing a lenticular mass of loamy sand the gravel showed no sign of bedding. Another part of the pit gave a section at a lower level, in about 5 feet of rather coarse gravel, composed chiefly of chalk pebbles, with smaller angular and subangular flints, and with signs of bedding (or of current-bedding?). This gravel rises in a dome-shaped mass, and is overlain by very coarse gravel, composed of large waterworn flints, with boulders of chalk and of carstone and some nodules of the last. There is a marked difference and a sharp division between these two gravels. The pit is at the eastern end of a narrow strip, which lies on the northern brow of the hill and may reach further west and south than is shown on the map; but there is no trustworthy evidence of this."

Of the small patches on the slope westward of Massingham Common, MR. WOODWARD says that "they take the esker-like form," and the mapping shows this character, the set occurring along a slightly curved line. One patch occurs directly on the other (northern) side of the marl in the Gaytonthorpe Valley, and in this MR. HAWKINS saw "a small pit close to the road, and about two thirds of a mile eastward of the Peddar Way, showing 5 feet of loose flint gravel."

Of the masses eastward from Massingham Common, MR. WOODWARD remarks that "the boundaries of the sand and gravel are not well-marked, up to Rougham. On Massingham Common there are many old disused pits, from 2 to 4 feet deep, and only 8 to 12 across, sometimes double, and reminding one of the so-called pit-dwellings."

"The gravel and sand from Rougham to Litcham Heath is clearly newer than the Boulder Clay, as it may be traced over the latter at Rougham, and I saw it in section above the clay in a pit north of Weasenham Lings. Eastward it is in a valley, and at Weasenham Heath rests in places on the Chalk. A pit S.E. of Weasenham Hall showed 12 feet of coarse flint-gravel, rudely interbedded with sand in the lower part, but in the upper confusedly arranged, the stones lying, for the most part, with their longer axes vertical."

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"In Mr. H. M. Jenkins' map of the Lodge (or Emanuel) Farm N.N.E. of Castle Acre, gravel is marked in the bottom of the valleys. This is, for the most part, a modern wash of sand and gravel; but here and there, as N.W. of the farm, are outlying esker-like patches. The author rightly points out that these deposits have nothing to do with the Nar or its valley."*

Two patches in the lower part of the valley at Gaytonthorpe have been coloured as Glacial, but without good evidence. Of the Drift here Mr. Hawkins says:—"About half a mile westward of Gaytonthorpe Church, Boulder Clay occurs in a pond on the southern side of the wood and the eastern side of the road. This clay does not extend far at the surface, being covered on the south and west by low-lying and probably thin Valley Gravel, whilst on the east it is overlain by gravel of greater thickness and possibly of older date. This older gravel runs up the valley for rather more than a quarter of a mile, forming a low hill, a pit in it showing 4 feet of flinty material. In the other patch several shallow excavations, on the western side of the lane close to the brick-kiln, show sand."

Sundry patches of gravel that occur over the Lower Greensand will now be noticed.

The ground just north of Ash Wicken was troublesome to map, especially as the map is not good here. Perhaps some of the clay coloured as Drift may belong to the clayey beds of the Lower Greensand, and perhaps some may be Gault; but it was not safe to map either of these. It has been found convenient to colour this with the marine clay next to be described. In the field by the high road north of the Hall, and west of the road thence to the Hall, some of the clay is red.

It will be seen that the three patches of gravel from Chilvey House to between Leziate and Ash Wicken occur along a slightly curved line, and that the most easterly is long and narrow. This is suggestive of an esker-ridge.

The map is much out eastward of Chilvey House, and therefore the geological lines had to be drawn wrongly, to fit it. The probable gravel-patch is really rounder than shown, though, even as shown, it is still carried a little too far north.

The gravel at Leziate seems, in great part, to rest directly on the sand of the Lower Greensand; but in places on Boulder Clay, and, south of the high road, mostly on the clean whitish and grey clay, which therefore may be of Glacial age. The gravel contains pieces of Kimeridge Clay and many pebbles of chalk.

Over the Chalk-tract north of the Gaytonthorpe Valley are many small patches of gravel of some interest. Some of these, on the high ground eastward of Grimston, are along a curved line that seems to run, with reversed curvature, into the line already described, from west of Massingham Heath to east of Rougham. Those further north, in the valley on the north of Grimston Heath, seem to be a direct continuation of this last line. The whole have an esker-like character, and one patch is of an exceptional kind, at one end filling a deep hollow in the Chalk and at the other forming on one side a ridge over the Chalk, an occurrence of which I cannot recall another example.

A pit on the hill E.N.E. of the Union House, S.E. of Grimston Church, showed at one part about 9 feet of irregular gravel, mostly coarse, the lower part chalky and with pebbles of chalk, the upper part less so, or not at all chalky. The stones were chiefly flints, but there were many pieces of ferruginous stone, from the Lower Greensand. At another part the gravel was chalky to the top, and a few pieces of Red Chalk were seen. This section is between the two hedges marked on the map, and westward is a large overgrown pit, north of the hedge, showing some gravel, some sand, and at one part chalk. In the field just N.W. there were shallow openings in the gravel.

* *Journ. R. Agric. Soc*, ser. 2, vol. v. p. 462. (1869.)

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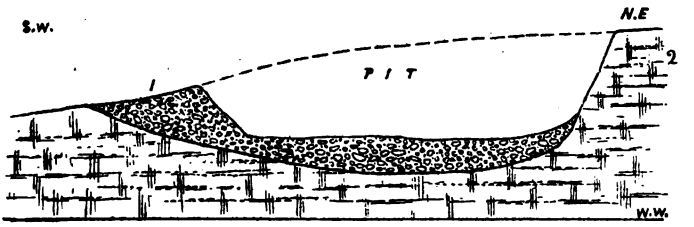
At another pit (? eastward) on this patch of gravel, open later (1886), the gravel was crowded with chalk pebbles and contained some boulders and many phosphatic nodules.

The gravel-ridge on the north of Gayton Field, and about 1½ miles N.N.E. of the church, is peculiar and of some interest. Whilst on the west it has a marked sharp slope, ending suddenly against the Chalk below; on the east it is much less clear, ending off partly almost level with the gentle Chalk-slope. Just south of the roadway, too, the gravel behaves very strangely, plunging down into the bottom of a pit, of which the eastern and higher side (30 feet or more in depth) consists of bare chalk. On the much overgrown western side there is, besides the gravel and sand, chalk-rubble, some signs of chalk, and, at one place, stony clay and a little of the usual buff chalky Boulder Clay.

The gravel in this pit is also remarkable for containing many large blocks of chalk, up to over 3 feet in length, and many also of fossiliferous shimmering Neocomian sandstone, with phosphatic nodules. There are also in it many chalk-pebbles and some masses of sand, some at the bottom being light-coloured, coarse, and with grains of chalk.

The southern (and highest) part of the pit was overgrown; but the gravel there seems to go right up to the top, where it was shown. If so there must probably have been some 50 feet of it, as the base was not touched in the bottom of the pit. The chalk of the eastern side (which is rather hard and with *Rhynchonella Cuvieri*) must be an old cliff, the section across the pit being as in Fig. 20.

FIG. 20. *Section across a Pit on the North of Gayton Field.*



1. Gravel and sand.
2. Chalk. A few flints seen only in the rubbly top part.

There was a small gravel-pit, still higher up, in the little wood just east.

Of the next two patches to the east, the first of which is larger, MR. HAWKINS contributes the following notes:—

"A pit by the side of the farm-track in Gayton Field, and about 1½ miles N.E. of Gaytonthorpe church, showed some 6 feet of bedded grey and brown sand, with a few small angular flints, and, at the base, a thin layer of fine angular flint gravel. Below this came some fairly stiff clay, full of broken *Belemnites* and perhaps 4 or 5 feet thick; but the thickness was made uncertain by talus, which hid the section. Below the clay, which may be a transported mass of Gault, was very hard chalk."

"On the southern side of Grimston Heath a narrow strip of gravel runs along the brow of the hill for about half a mile; but it was difficult to fix its eastern boundary."

The set of patches in the valley to the north continue along that valley in Sheet 69, and it was these of which the esker-like form first struck me, in 1882, when working in Western Norfolk. Though in the bottom of the valley they often rise up above the immediate outcrop of the chalk on the flanks, and though small, they make a marked feature, both in form and in vegetation.

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CHAPTER 10. POST-GLACIAL DRIFT.

Doubtful Nature of Classification.

In the first place, as in various other Memoirs, attention must be drawn to the fact that the term Post-Glacial is somewhat vague, and that the beginning of the geologic period thus named is probably different in different parts of the country. Nature has drawn no hard and fast line between Glacial and Post-Glacial times, the former having lasted longer, under favourable circumstances, in one district than in another, where a less rigid climate set in earlier: warmer conditions would naturally hold in the south sooner than in the north.

Locally, however, there is often little doubt as to the division between Glacial and Post-Glacial beds, and it is in this local and limited sense that the latter term is now used: it means only beds that are newer than the Glacial Drift of the district, without reference to that Drift in other parts. I take it that like views should hold with other geologic formations, whereby much useless controversy as to the correlation of distant deposits would be avoided: we are apt to judge from our own limited local knowledge, and to expect the rest of the world to conform thereto, forgetful of the fact that Nature is not given to ruling a set of parallel lines, but prefers irregularity; for which indeed we ought to be thankful, instead of striving after unnatural regularity.

Besides this general matter there are, however, some more special troubles. Some of these refer to the position of certain beds, of which the age is doubtful; and it is quite possible that some gravels described in the last chapter should have been treated here. Others are connected with the difficulty of making out the relative ages of the various members of the Post-Glacial series, some of which seem to be apart topographically, though chronologically they may not be so distant. Under these circumstances it has seemed advisable to treat of the various beds either by means of a convenient local arrangement or by reference to their origin, where that can be made out or fairly inferred; and it is of interest to note that we have largely to do with marine conditions, instead of being confined to freshwater ones, as in some districts.

One of the marine beds in question, the clay of the Nar Valley, moreover occurs only in our district, and there over a comparatively small tract, unless represented by unfossiliferous clay just to the north; and the other, the shelly gravel of March and of other islands in the Fens, is local to the Fenland.

It must be understood, therefore, that the grouping adopted does not imply that the beds have been altogether formed in the order in which they are described.

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NAR VALLEY BRICKEARTH.

General Note and Literature.

We now come to the description of a set of clayey beds that have sundry peculiarities. In the first place their range is a narrow one, being limited to the Valley of the Nar and its neighbourhood. Secondly, they contain a number of marine shells, clearly proving a submergence which, though of no very great vertical amount, yet must have had a marked effect in so low a country. Thirdly, all the sections in them, for various brickyards, had long been closed when the Geological Survey entered the district, and were then hidden and overgrown; so that all to be seen was for the most part in an occasional open ditch. Nearly all our information, therefore, comes from our fore-goers, and it is very lucky that, at the time when the pits were open, so good an observer as MR. ROSE was living in the neighbourhood: had it not indeed been for his careful record of the sections, together with his zealous collection of the shells, our knowledge of these beds would have been but small. His paper on West Norfolk, already oft-quoted, will be again laid under contribution, and, with later ones, special to the subject, will form our chief store of facts. It is some pleasure to me to have a personal remembrance of MR. ROSE, though dating from long before I worked in West Norfolk.

These shelly beds, or their shell-less equivalent, reach down to the level of the marshes and up to perhaps some 50 feet above that. I believe that they have never been seen resting on any other member of the Drift (except perhaps in one doubtful case, noticed further on) and even that their base has been seen only at one place; but, in our mapping, they were traced beneath the River Gravel of the valleys. In age, therefore, they seem to rank as early Post-Glacial at least.

On the map sundry tracts of a like clayey character, and in a like position to that taken by the shelly clays, have been classed as belonging to the same series (as in one case, indeed, occurred to MR. ROSE); the mere accident of containing shells not being enough to warrant a division between shelly and shell-less clays. It must be understood, however, that here again, as with other divisions of the Drift, there may be doubts as to classification, and that some of the unfossiliferous patches may even belong to the Glacial Drift.

The first account of the Nar Brickearth is, I believe, by A. YOUNG, who says that from West Bilney "for ten miles to Wallington [Watlington?], there is a remarkable bed of oyster-shells in sea mud."*

S. WOODWARD'S allusion to the deposit comes next, and consists of a short paragraph, a reference to ROSE'S collection, and a list of nine species of shells.†

* Agricultural Survey of Norfolk, ? 1804 and 1813.

† An Outline of the Geology of Norfolk. 8°. *Norwich*, 1833, pp. 13, 32, 36, 57, tab. 1.

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Three years later Mr. Rose himself described the deposit in detail,* having, in the earlier part of his paper (1835), given a map on which the position of the sections are noted, a most useful thing to do. He names it "*Brickearth of the Nar*," from "having (till very recently) found it only in the valley through which that river takes its course. In this valley I have traced it west and east from Watlington through East Winch and West Bilney to Narford, a distance of nine miles. It occupies low ground, except at its inland extremity, where it rises to about eighty feet [?] above the level of the Nar. . ."

"The clay inclosing the shells is of a slate blue colour, and upon drying falls into laminæ; it contains numerous spangles of *mica*, and in the lower part of the bed at Winch and Bilney there is a considerable admixture of sand. It has a very muddy smell when first opened, and the water which rises from it is too offensive to be used for culinary purposes. No *boulders* have been found in it. . ."

Thus "within the valley of the Nar there occurs an extensive deposit of mud, containing marine shells, the living congeners of which inhabit the adjoining sea. . ."

"We are therefore led to infer that this valley was, at a remote period, occupied by the waters of the ocean," and "we cannot doubt that the valley of the Nar at a former period opened directly into the estuary [the Wash], and that the ocean's waves flowed freely into the valley, forming an extensive creek."

In his paper of 1840† Mr. Rose repeated much of the above, and added that "the general thickness of the bed of clay . . appears to vary considerably, being modified by the irregularities of the surface on which it was deposited . ."

"The shells are generally interspersed throughout the clay; but the oysters are also found congregated in layers, as are likewise the corbulæ."

The Rev. G. B. Moxon had a paper on the subject, immediately following the above,‡ in which, however, he also referred to deposits really of different age and origin.

Seven years later J. Trimmer referred to the Nar beds,§ but his remarks are chiefly in the nature of a notice of Rose's work, or in reference to his own views of classification. He objects to the name "brick-earth, by which loam is usually understood, whereas it [the deposit] is in reality a blue clay;" he says, "From the marine shells which it contains, their state of preservation, and the manner in which the species are grouped, it appears to have been an estuary deposit;" and he notes that whilst the shells "are all of existing species now inhabiting the British seas," yet "they differ from those found in the marine silt of the adjoining marshes, which are the group still living in

* *Phil. Mag.*, ser. 3, vol. viii. pp. 30–34. (1836.)
† *Proc. Sci. Soc. Lond.*, vol. ii. pp. 61, 63.
‡ *Ibid.*, vol. ii. pp. 63, 64.
§ *Journ. R. Agric. Soc.*, vol. vii. pp. 469–471. (1847.)

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the existing estuary. They are accompanied, in some of the pits, by broken bones and teeth of the horse, elephant, and rhinoceros." His later allusion to the subject adds nothing to the above.*

We have next MR. ROSE'S final paper on the subject,† the new matter in which consists of the statement of his "conviction that the geological era of this Nar deposit coincides with that of the Post-tertiary deposits of the basin of the Clyde," of notes of additional localities, and of a fuller list of fossils. To this last PROF. T. R. JONES soon after contributed a note on the few Microzoa found, in which he says that the four Entomostraca are new species and the three "Foraminifera are evidently from very shallow waters, possibly estuarine, or a few fathoms in depth."‡

In 1868 MR. GODWIN-AUSTEN, in his Presidential Address to the Geological Section of the British Association, accepted ROSE'S conclusions as to the age and origin of the deposit.§

A few years later MESSRS. S. V. WOOD, Junr., and F. W. HARMER‖ alluded to the deposit, which they classed as Post-Glacial, saying "Its fauna . . consists entirely of species still living, and which, with one exception, occur in British Seas. The shells of this formation are in fine preservation; and there can be little doubt of the deposit being one of an estuary connected with that sea, which a Post-glacial depression . . caused to overflow the lower elevations of the eastern side of England."

Two years after MR. S. V. WOOD (the elder) gave a full revised list of the shells.¶

In his note on the deposit** MR. SKERTCHLY unfortunately reproduced the older list of fossils given by Rose, instead of the revised list of Wood. He said that the beds are "probably contemporaneous with the beach gravels [March, etc.] . . and the occurrence of the woolly elephant and rhinoceros is suggestive of inter-glacial age."

The last contribution to our knowledge of the Nar clay, from MR. S. V. WOOD, Junr.,†† dealt with its classification and correlation. He classed it with his "Cyrena-formation," a division of the Post-Glacial Drift including those beds, in the valley of the Thames and elsewhere, that are noted for containing shells of *Cyrena* (or *Corbicula*) *fluminalis*, a species now extinct in Britain. For my own part, however, I do not see good reason for divorcing these particular brickearths, etc., in the Thames Valley from the rest of the River Drift, which does not happen to

* *Quart. Journ. Geol. Soc.*, vol. vii. p. 23. (1851.)
† *Geol. Mag.*, vol. ii. p. 8. (1865.)
‡ *Ibid.*, pp. 306, 307.
§ *Ibid.*, vol. v. p. 480 (1868), and *Rep. Brit. Assoc. for* 1868, *Sections*, p. 58. (1869.)
‖ Supplement to the Crag Mollusca, Part i. p. xxix. *Pal. Soc.*, 1872.
¶ *Ibid.*, Part ii., pp. 203, 204, 206, 207, 209, 212–218. (1874.)
** The Geology of the Fenland, pp. 234, 235. (1877.)
†† *Quart. Journ. Geol. Soc.*, vol. xxxviii. p. 698. (1882.)

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yield that particular shell. As regards less distant deposits our author groups in this division the Cambridge (Barnwell) gravel, noted for its land and freshwater shells, of which he considers the Nar clay to be a marine continuation, the gravel at Hunstanton, and that at March, both with marine shells, the last being, however, the only deposit in our present district in which *Corbicula fluminalis* has been found.

The only serious mistake that has been made on the subject was in the discussion on this paper, when the present writer rashly suggested that the Nar clay might be almost as modern as Thames mud. This mistake resulted from the want of personal knowledge, though I had then read all that had been written on the subject. Happily for me I was left to correct my blunder, in an address given in the following year,* in which the deposit was suggested to be "a shelly accident in a mass of brick-clay, that, elsewhere shell-less, has attracted no attention."

The mapping of the Nar clay shows that in the valley of the Nar there is no outcrop for a distance of some miles, from above the eastern end of Wormegay to Narborough. Moreover, though much of that part is taken up by alluvium (by which underlying beds are hidden), yet, where that is not the case, neither has any trace of the clay been found above the Lower Greensand and Gault on the northern bank, nor was any sign of the clay seen beneath the Gravel or Chalk on the south. The deposit indeed seems here to have nothing to do with the main valley, but to occur along the tributary that runs north-eastward, between East Winch and West Bilney, turning again to the main valley northward of Narborough.

It is to be noted that the direct upward course of this tributary-valley is to Gaytonthorpe, where the stream rises, and above which place the bottom of the dry valley is filled with a marly deposit, with freshwater shells. This tends to the suggestion that the two deposits may have some connection, as seems to have been in TRIMMER'S mind.†

Fossils.

In the following list the names of the Mammals are taken from Rose's paper of 1865; those of the shells from Wood's Supplement to the Crag Mollusca, with three, marked R, added on the authority of Rose's paper, but which, not having been endorsed by Wood, may be taken as doubtful; the three Articulata, again are from Rose's paper, and the Microzoa from Prof. Jones' note of 1865. The synonymy has been corrected by MR. G. SHARMAN.

The localities being all near together there seems to be no need to specify them.

Mammalia.

Bos. Teeth.
Cervus elaphus, *Linn.* Fragments of antlers.
Elephas primigenius, *Blum.* Teeth and vertebra.
Equus caballus, *Linn.* Teeth.
Rhinoceros tichorhinus, *Cuv.* Fragments of teeth.
Bone of Ruminant.

PROF. T. R. JONES found a few otolites of fish in the residue of washings.

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* *Proc. Norwich Geol. Soc.*, pt. viii. pp. 284, 285. (1884.)
† *Journ. R. Agric. Soc.*, vol. vii. pp. 471, 472. (1847.)

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Mollusca.

Aporrhais pes-pelicani, *Linn.*
Buccinum undatum, *Linn.*
Cerithium reticulatum, *Da Costa.*
R. Hydrobia (Paludestrina) ulvæ, *Pennant.*
Littorina littorea, *Linn.*
R. „ obtusata (?), *Linn.* (= litoralis, *F.* and *H.*).
Nassa incrassata, *Müll.*
„ pygmæa, *Lam.*
Natica Alderi, *Forbes* (= nitida, *F.* and *H.*).
Pleurotoma septangularis, *Mont.*
Turritella terebra, *Linn.* (= communis, *Risso*).

Abra alba, *W. Wood* (= Syndosmya, and Anomia or Placunomia patelliformis).
Cardium echinatum, *Linn.*
„ edule, *Linn.*
Corbula gibba, *Olivi* (= nucleus and striata).
Mactra solida, *Linn.*
R. „ subtruncata, *Da Costa.*
Montacuta bidentata, *Mont.*
Mya arenaria, *Linn.*
Mytilus edulis, *Linn.*
Ostrea edulis, *Linn.*
Pecten varius, *Linn.*
Scrobicularia plana, *Da Costa* (= piperata, *Aldrov.*).
Tapes decussatus, *Linn.*
Tellina balthica, *Linn.* (= solidula).
„ lata, *Gmel.* (= proxima).

Articulata.

Balanus. Echinus miliaris, *Serres.* Vermilia triquetra, *Mont.*

Microzoa (*Entomostraca* and *Foraminifera*).

Cythere arborescens, *Brady.*
„ aspera, *Brady.*
Cytheridea punctillata, *Brady.*
Normannia carinata, *Brady.*
Nonionina depressula (rare and small).
„ striato-punctata (common and small).
Rotalia Beccarii (common).

Details.

It will be convenient to take the description firstly along the southern side of the Nar, going up the river; then down the northern side of the river; and lastly such patches of clay to the north as have been, more or less for convenience sake, classed with this deposit, though without shells.

Mr. Rose noticed the occurrence of the Nar clay at Watlington, but without giving any detail of the site. Perhaps it was at some of the places now to be noticed.

Eastward of Watlington Church clay crops out in the bottom of the little side-valley, and there may be an outcrop northward, down that valley, bordering the marsh, and joining on to the slight outcrop mapped at Tottenhill Row; for loam was seen on the west of the marsh, whilst on the east, I saw some clay, with bits of shell, in a ditch about a third of a mile north-eastward of the church. Farther northward, close to Tottenhill Row, there is a spring; so that, perhaps, the gravel bordering the marsh may be only a wash from that of the higher ground eastward: there was, however, hardly enough evidence to justify the mapping of clay here.

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The narrow outcrop from beneath the gravel, mapped along the edge of the fen, just W. of Tottenhill Row, very likely joins on by a mere streak (too narrow to show on the map), to the larger outcrop from that place north-eastward, for about half a mile, in which, at about the middle, the clay was seen in a pond, beneath a little gravel. Presumably all this is Nar clay. Mr. Hawkins, who examined a specimen of purplish clay, taken by me from here, tells me that "the residue, after washing, consisted of grains of quartz, mostly angular, but a few rounded."

Mr. Rose says: "At Tottenhill brick-yard . . the same bed of blue clay is met with, inclosing similar shells to those at West Bilney."* But from his description, and from the map in the earlier part of his paper, it is clear that this is on the eastern side of the high road close to the marsh, and is not the brickyard noticed by Mr. Hawkins further on, and to which Mr. Rose's later note (1865) presumably refers.

Mr. Hawkins, who surveyed all but the above patches, in the southern tract, says that, at the junction of the valleys of the Nar and Ouse, "the Nar clay seems to underlie the gravel N. of Tottenhill, over a fairly large area, and many pits have been dug to get the former, either for brickmaking or for spreading over the land as a manure. Of late years, however, it has not been used for either purpose, so that there were no clear sections (in 1883), the old pits being full of water or otherwise obscured."

"The clay shown in the pits on either side of the road from Tottenhill to Watlington, an eighth of a mile W. of the high road, probably belongs to this deposit."

"At the brickyard (northward of the village of Tottenhill, and three-quarters of a mile N.W. of the church), the clay was dug to a depth of 15 feet, according to a local informant; but there was so much water in the pits that only the upper part could be seen, and that very indistinctly." We must therefore give Mr. Rose's section† :—

Soil, and loam with many flint-pebbles, some as large as oranges, and a few angular flints; 3 to 6 feet.

Blue brick-earth, with but few shells until near the bottom of the pit (14 feet deep). Large oyster-shells in a layer at a depth of 12 feet, and beneath this shells of *Aporrhais pes-pelicani* and of other molluscs, plentifully scattered, and some blackened fragments of wood.

Blackish sand of the Lower Greensand.

Mr. Hawkins continues:—"A little north-eastward, at the edge of the wood and near the large gravel-pit, the clay is found in a pond, which has been dug through the gravel."

"Near the five-mile-stone, on the high road a little N. of the brickyard, there were several pits in the clay, which is also found in the ditches by the road-side."

"Clay is also to be seen by the edge of the fen a quarter of a mile N.E."

"East of the brickyard there was a pit in the clay, at the corner of the lane leading down to the fen, and before the fen is reached the clay may again be seen by the side of this lane for about an eighth of a mile."

"Just opposite the top of the lane there is a round pond in the clay, on the western side of the high road; and from here there seems to be an outcrop down the slope to the water-course."

"In Wormegay (a large island in the fen in which Rose seems not to have noticed these beds) there are many pits, in one of which a great thickness of the clay was found."

"A quarter of a mile below the bridge over the new deep drain (through the eastern end of the village) a little of the clay is to be seen, and eastward it may be found in ditches, below a thin covering of sand and gravel."

"A little more than half a mile N. by W. from the above-mentioned bridge were two pits in the clay, on either side of the E. and W. cart-track. On the southern side of this track, further eastward, were two more clay-pits, and another was seen to the south, a quarter of a mile S.W. of where the track joins the road on the east. All these pits have been dug through sandy gravel to the clay below."

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* *Phil. Mag.*, ser. 3, vol. viii. p. 31. (1836.)

† *Geol. Mag.*, vol. ii. pp. 10, 11. (1865.)

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"About an eighth of a mile east of the junction of the track and road a very large pit has been made, but it was full of water, as also were the others. Here the clay was dug to the depth of 35 feet."

"At the north-eastern end of the island the clay that comes to the surface over a small area belongs probably to this deposit."

From here, on the southern side of the Nar, nothing was seen of this clay for more than 5 miles.

Mr. Rose records that "at Narford, near the Hall, in the same fetid blue clay as at Bilney, *Ostreæ*, accompanied by *Rostellariæ* [*Aporrhais*], were discovered beneath a considerable bed of sand and loam; the clay was sunk through at the depth of 27 feet, and in its lowest portion teeth and vertebræ of . . Elephant were found."* In a later paper he notes that the men "it is said found a bed of gravel beneath [the clay] reposing upon the chalk."† This is probably the old pit noted by Mr. Hawkins as "a quarter of a mile N.E. of Narford Church, on the eastern side of the road leading across the river. It is full of water, and is said to have been dug for clay, through the sand at the surface, for spreading over the land, as a manure."

Of the clay next to be noticed Mr. Hawkins says that "it is very doubtful whether the clay in the brickyard, by the edge of the marsh about three quarters of a mile below South Acre church and half a mile E. of West Acre Mill, is Nar clay. The section showed a thickness of about 3 feet of stiff blue clay, weathering brown and grey and drying into hard tough masses, with some small weathered fragments of flint and a few large flints, and passing up into sand, which rapidly changes into sandy gravel."

Crossing to the right bank of the Nar we come to a high strip of shelly clay, coming out from between the Gravel and the Chalk on either side of the road from Narford to East Walton, a little south of west from West Acre church. This seems to be the spot alluded to by Rose in his earliest papers, where he says that in a pit at East Walton (marked on his map as on the eastern side of the road) shells may "be seen imbedded in a light-coloured alluvial clay, rising abruptly from the valley of the Nar to a height of eighty [?] feet above the level of the river: the shells are much more broken than those found in the blue clay, situated at a lower level."‡ I doubt though whether there is any need of his theory that the presence of the shells at such a height "was probably affected by spring tides in conjunction with storms casting them upon the shore of the creek." He also speaks of them as "rising to the surface at a considerable angle;"§ but one is at a loss to know whether he saw anything like a dip here, or whether he does not rather refer merely to elevation, though he speaks of "departure from their usual horizontal position."

The shelly clay was still to be seen in this old pit at the time of my visits, and also in another some way west of the road. Mr. Hamond, of West Acre, has some bones from the clay north of Narford, presumably from this patch.

"On Pentney Warren [? Walton Warren of the map] . . I found a moor (peat) containing all the freshwater Shells of the neighbouring rivulets, lying immediately upon the marine brick-earth. In other parts of the Warren the brick-earth appears in a regularly horizontal bed, from three to four feet beneath a deposit of sand containing small angular flints."‖ I saw the shelly clay, in a pit, through the gravel on the eastern side of the brook, close to the south-eastern end of this fairly long outcrop, and again just S. of the gravel on the western side of the road across its middle part; whilst in a like position, close to the farm near the western end of the outcrop, an old pit seemed to show clean clay over Boulder Clay, perhaps the only junction of the Nar beds (presuming the upper clay to belong thereto) with Glacial Drift.

Mr. Rose continues, "On East Walton Common . . may be seen in the margin of a pit containing water, a layer of large Oyster-shells eighteen inches below the surface of the ground; and four feet below this layer, the Oysters, with *Aporrhais pes-pelicani* and other Shells, their usual associates,

* *Phil. Mag.*, ser. 3, vol. viii. p. 31. (1836.)
† *Proc. Sci. Soc. Lond.*, vol. ii. p. 62. (1840.)
‡ *Phil. Mag.*, ser. 3, vol. viii. pp. 31, 33. (1836.)
§ *Proc. Sci. Soc. Lond.*, vol. ii. p. 62. (1840.)
‖ C. B. Rose, *Geol. Mag.*, vol. ii. p. 10. (1865.)

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are jumbled together in great abundance."* In this outcrop I saw shelly clay at the following places:—A third of a mile westward of East Walton church; in the stream nearly three quarters of a mile west of the same; a little further westward, by the south-eastern corner of Hollands Wood; rather more than halfway from the northern edge of that wood to the road on the north; south-eastward of the meeting of that road and the track to West Bilney; and just east of this track, on the northern edge of the wood marked on the map.

In his last paper Mr. Rose said, "In a drain at the back of Mr. Spinks's farm-house, near to West Bilney Church, the section is as follows" †:—

Soil, and then silt, to the depth of 4 or 5 feet.
Peat, with roots, &c., a foot.
Brickearth, with the characteristic shells.

Mr. Rose has stated that "Two hundred yards to the north of the Carstone-pit at the back of Bilney Hall [Lodge], in the valley, on Bilney Common [not named on the map] . . is a pit among fir-trees, where I observed" the following section:—

Sandy ochraceous loam, with small angular flints; a foot.
Grey sandy loam; 2 feet.
Blue clayey earth, as at the brickyard, with oyster-shells; 4 feet.

And he adds, "In a portion of this pit a moor (peat) is visible lying upon the brick-earth, in which I understand Mammalian remains have been discovered."‡

Mr. Rose said that at West Bilney "a well was sunk to the depth of forty feet, and *Ostreæ* and *Rostellariæ* [*Aporrhais*] were still brought up; but the oysters were most abundant at the depth of three or four feet . . Two fragments of the grinding teeth of the *Ox*, and small portions of bone, were also found in the blue clay, at the depth of five feet."§ In a later paper he added that "the lower portion [of the Nar beds] here becoming very arenaceous, it is probable that the workmen approached close upon the green-sand beneath."‖ The site of this well is not precisely stated; but it seems to be at the brickyard, which was on the northern side of the road nearly three quarters of a mile north-westward from West Bilney church, of which Mr. Rose says:—"At West Bilney it [the clay] is generally covered by two or more feet of earth, consisting of vegetable soil, and yellow sandy loam, containing small pebbles and angular fragments of flint . . At another part of the brick-yard bleached shells . . are found immediately beneath the vegetable soil in white sand: the same [species of] shells are also scattered through the brick-earth."¶

I saw the shelly clay in the ditch on the other side of the road.

The next section to be described was nearly 1¼ miles E. of East Winch church, on the northern side of the road where the railway crosses it, and the beds shown were as follows**:—

Sand and loam, with fragments of a tooth and bones of elephant and a broken tooth of rhinoceros; 7 feet.
Light-coloured clayey earth, with a few shells; 6 feet.
Blue clay, with shells in abundance; 10 feet.

In his last paper the same author says:—"At East Winch Brick-field, now levelled and deserted, the blue clay (mud) varies in thickness from two to twelve feet, and towards the deeper part it becomes a sandy silt, containing shells (particularly Oysters) in great abundance. . . In this yard, between the old diggings and the road, the brick-earth lies within a foot of the surface; it is light-bluish-brown clay, gradually passing into a blackish-blue as it descends. . . At the surface of the clay, or rather in the upper few

* *Geol. Mag.*, vol. ii. p. 10. (1865.)
† *Ibid.*, p. 9. (1865.)
‡ *Ibid.*, pp. 9, 10. (1865.)
§ *Phil. Mag.*, ser. 3, vol. viii. p. 31. (1836.)
‖ *Proc. Sci. Soc. Lond.*, vol. ii. p. 61. (1840.)
¶ *Phil. Mag.*, ser. 3, vol. viii. p. 31. (1836.)
** Rose. *Ibid.*, pp. 31, 32.

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inches of it, shells of *Corbula nucleus* are profusely distributed, affording unmistakable evidence of its being an original bed of that mollusc."*

On the railway, about half a mile eastward of the station, oyster-shells were seen, and to the south-east (on the other side of the road), shelly clay. Loam with shells was seen at the angle of the road, about a quarter of a mile north-eastward of the Hall, and shelly clay by the side of the plantation north-westward of the Hall.

"In the middle of the village of East Winch, by the side of the road leading to Lynn, *Ostreæ* and *Rostellariæ* [*Aporrhais*] were discovered on sinking a well; and on Mr. Forster's farm . . similar shells were found."† This farm seems to be the one more than half a mile southward of the church, near which was the following section, noted in Rose's last paper.

"In East Winch, at the late Mr. Foster's brick-yard, I observed that immediately beneath the vegetable soil lies a coarse red gravel . . here associated with a loam . . The gravel and loam vary in thickness from two to seven feet; then appears the blue earth, which has been sunk into eighteen feet. It becomes darker as you descend, and at the depth of six feet you meet with large Oysters, forming layers, and a few are interspersed through the clay, associated with" other shells.‡

It will be seen that this outcrop, which is by far the largest of the deposit, has been mapped as reaching westward, along the southern side of the valley of the Middleton stream, to just beyond Middleton Tower End. Although clay was often seen, in no place were shells found; but Mr. Rose remarked, in his earliest paper, that "The same kind of blue clay was opened last summer about half a mile to the south of Middleton Tower . . *Ostrea edulis* and *Turbo littoreus* were found six feet below the surface."§ Judging by his map, however (1835), the site was south-eastward of the Tower.

Two patches of grey clay and loam, which crop out on either side of the gravel S. of West Winch, may belong to the Nar beds, but no shells were seen in them. The clay differs from the Kimeridge Clay close by, being buff and grey where seen in the middle of the southerly outcrop, and light-bluish-grey and sandy in the smaller northerly one.

The Middleton section is the last record of shelly clay, and the patches of clay to the north, at Ash Wicken, at Grimston Warren, and at Grimston Common, have been classed with the Nar beds rather as a matter of convenience, and to avoid the introduction of further and baseless nomenclature.

At Ash Wicken the relation of the clean clay to the Boulder Clay could not be made out when I was there, and the only record found merely says that "the pit . . is deep, close to gravel."‖

The cutting on the old line of the Eastern and Midlands Railway south of Grimston Warren was being widened and deepened, in November 1881, along the northern and higher side. The shallow western end was in grey clay; but eastward this sank and again rose, and then sand and gravel came down rather suddenly, as if cutting into the clay. In the middle part of the cutting this clay passed into, or up into, buff laminated loam and sand, partly gravelly, of which up to 4 feet was seen, and at one part this seemed to pass up into the false-bedded sand and gravel above. The eastern end was in light-bluish-grey clay.

Clay again occurs, to a greater extent, on the eastern side of the tributary valley, along the western and northern parts of Grimston Common. In the brickyard on the north, and about 1½ miles westward of the church, there were, in 1883, shallow-pits in light-grey or whitish clay, with small concretions (race); but Lower Greensand clay, from the pit on the other side of the Common (see p. 19) was also used.

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* *Geol. Mag.*, vol. ii. p. 9. (1865.)
† Rose. *Phil. Mag.*, ser. 3, vol. viii. p. 32. (1836.)
‡ *Geol. Mag.*, vol. ii. p. 10. (1865.)
§ *Phil. Mag.*, ser. 3, vol. viii. p. 32. (1836.)
‖ The Rev. G. B. Moxon, *Proc. Sci. Soc. Lond.*, vol. ii. p. 64. (1840.)

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CHAPTER 11. POST-GLACIAL DRIFT.

River Gravel.

General Note.

We now come to a set of gravels that occur along the valleys, and which seem to have some connection with the present river-system, though mostly with an early stage of it. Although no evidence of fluviatile origin, in the shape of contained shells, has been found over by far the larger part of these gravels, yet their position, either skirting the fen, or forming a terrace not far separated from it, is so much like that of River Gravels in other parts of the South of England, that there can be little doubt as to the classification.

Nor can we doubt either that these gravels are of later date than any of the Glacial Drift of the district, from their occupying valleys that have been eroded through the latter and from their resting on the Boulder Clay, whenever that deposit slopes down to the lower levels, so that the two Drifts come together. Where too the gravel with which we are dealing comes in contact with the Nar clay, the former goes over the latter, which is itself newer than the Boulder Clay.

Should any of this gravel turn out to be of marine origin the above conclusion as to age will not be invalidated, for we have next to deal with a marine gravel which holds a like position, and which all geologists who have studied it, with probably only one exception, hold to be Post-Glacial. It must be remembered that we may here be near the seaward end of our main valley, and that estuarine conditions may have prevailed in part of it, though as yet no evidence has been forthcoming.

Although connected with the present river-system these gravels were by no means formed by rivers like the present ones, which deposit only silt or other fine material. They must have been formed when the rivers had a greater carrying-power than now, and under less temperate conditions than now hold. There is no need here to enter into a discussion on the formation of the River Drifts, for which the reader is referred to a Geological Survey Memoir that deals very largely with this formation.*

In describing the River Gravels it will be convenient to group the details by the different valleys, taking first that of the main river, and then those of its tributaries, from the south northward, in all cases working down the valleys.

Valley of the Ouse.

In the southern part of our district the Ouse can hardly be said to have a valley, nearly all sign thereof having been abolished by the broad Fen through which the present stream has its more or

* The Geology of London and of Part of the Thames Valley, vol. i., chaps. 20, 21 (general account, &c. only). 1889.

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less artificial channel. The island of Littleport on the left (with the northern end of Ely) and Southrey with Hilgay on the right are the only tracts of ground rising fairly above the Fen and marking the borders of the valley. It may be however that we ought to take the Chalk of Feltwell as the eastern border; though, from the absence of any River Drift along the western edge of this Chalk, it would seem as if there had been a fair amount of erosion since the time of the River Drift, the Fen deposits coming up to the Chalk for some miles.

In this southern tract we have hardly any gravel that can with certainty be referred to the main valley. When however the Ouse comes to the mainland, near Downham Market, gravel occurs, firstly in a few separate patches, but then in what is probably a continuous sheet, the slightly separated masses joining on most likely beneath the marshes, except perhaps where cut through by the deep alluvial deposits of the tributary-valleys.

There is a notable point in the breaching of the gravel by these tributaries. In each case the tributary-valley narrows where it cuts through the gravel of the Ouse. Both in the case of the Nar and of the Middleton Stop Drain there is a marked low spur of gravel on either side, forming what may be called a breached bar, the gravel apparently having been able to resist erosion better than the underlying beds in rear. This effect is greatest in the largest valley, that of the Nar, whilst in the smallest, that of the Bawsey brook, it is least. Perhaps the small gap between Hilgay and the mainland may be the relic of another such narrowing, at the junction of the Wissey with the Ouse.

On the high ground of Littleport Fields Mr. Skertchly has mapped a mass of gravel, presumably the remains of a terrace of River Drift.

The sand and gravel of the island of Butcher's Hill, bordering the old course of the Ouse (Old Welney River) is probably part of a lower terrace (see p. 69).

Shrub Hill, W. of Hockwold, belongs most likely to the Little Ouse rather than to the main river (see pp. 96, 97).

The mass southward from Denver Station is cut through to Kimeridge Clay for some way, on either side of the railway. The gravel was seen over Boulder Clay by the northern corner of the little wood a quarter of a mile S.S.E. of the station. About a third of a mile southward there is gravelly sand.

In the strip, belonging to a higher terrace, above the railway northward from the station, the gravel at the eastern end of the Common, by the windmill, is hardened.

In the mass north-westward of Wimbotsham sand and gravel are shown along the railway.

The same is the case at Holme Common, in the longer mass from Stow Station to Holme.

The broader sheet of Watlington and Tottenhill, at the junction of the Nar Valley, is of more interest, from the gravel being seen in various places overlying the Nar Clay (see p. 86), and from its having been worked largely in places.

Gravel and loam were seen in a small pit on the eastern side of the road a third of a mile south-eastward of Watlington church.

In an old pit a quarter of a mile northward of the church there is clay at the bottom, but whether Nar Clay or Kimeridge Clay could not be seen. In a pit by the edge of the marshland N.N.W. however the gravel was not bottomed: its base seems to slope to the marsh.

I noted pits on the eastern side of the high road just westward of Tottenhill village, and Mr. Hawkins noted others "on both sides of the road from

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Watlington Hall to Tottenhill, the pit on the northern side being 10 feet deep, but with no clear section, whilst that on the south showed about 4 feet of fine gravel, very indistinctly bedded and consisting mainly of small subangular flints and flint pebbles, but with a few fragments of carstone and an occasional pebble of quartzite."

"Inside the bend of the road at the eastern end of Tottenhill Row old pits show 3 or 4 feet of pebbly gravel."

The largest pits are northward or north-westward of Tottenhill, and are thus described by MR. HAWKINS: "They take up a large area on each side of the high road (to Downham). In one part of the pit W. of the 5-mile stone, the gravel had been dug to the depth of 12 feet, and the following section was seen, in 1883":—

Fine angular and subangular flint gravel, and sand, apparently not bedded, resting very unevenly on the bed below, the top of which seems to have been ploughed into hollows before or during the formation of this gravel; about 7 feet.

Clayey sand, mottled grey and brown, with a few small flints, resting with a sharp even junction (inclined W. at an angle of 5°) on the bed below; 2½ feet.

Fine bedded angular and subangular flint gravel, which, like the top bed, contains many flint pebbles; 2½ feet.

"Some 80 yards N. the bed of sand disappeared, and the two gravels came together, the lower being there indistinctly bedded, and disturbed at the top, like the sand in the above section."

"At the extreme northern end of the pit the gravel seemed to have changed in character, as it consisted chiefly of small angular flints, with only a few pebbles, but with more large unworn flints and a few fragments of carstone. It was dug to the depth of 15 feet, the lower half being evenly and clearly bedded, but the upper very indistinctly, if at all: in fact it looked as if the gravel had been ploughed out in a great hollow and then redeposited, in several places."

"Along the road, still at the northern end of the pit, the gravel is again very pebbly, at least in the upper part. In several places this top pebbly gravel seems to have been disturbed, as is shown by its rising in ridges, in which the longer axes of the pebbles gradually take a vertical position: the ridges indeed could not be distinguished but for the change in the direction of the axes of the pebbles."

Further north gravel and sand were seen on either side of the high road, beyond the junction of roads, but the large old pit at the far north was abandoned.

In the tract next to the north, from Setchy to Hardwick, no sections of interest were seen, though there is plenty of evidence of the gravel, which may be just divided southward of West Winch church. Clay (Kimeridge) was seen beneath it in the Puny Drain about three quarters of a mile S.S.W. of West Winch church. The cutting on the new line of the Eastern and Midlands Railway, south of Hardwick, was turfed over, west of the high road, when I saw it, in 1886 (after the Survey had been made). One could however make out the junction of the thin gravel and the Kimeridge Clay. East of the road the cutting is chiefly in clay, but running apparently through some shallow old pits, whence the gravel has been taken away.

In the Gaywood strip again there were no sections to be noted, nor in that just north, until it passes into the district beyond (Sheet 69).

Valley of the Little Ouse.

Along the bottom of this valley, bordering the Alluvium on either side, and reaching a little way up the slope, are some long strips of gravel, some of which are of interest as having yielded a good number of flint implements, in consequence of which they have been much noticed. The following description is mostly

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taken from the work of observers who preceded the Geological Survey.

Some of the names of sites that have been used unfortunately are not on the map, and we have to begin with these. One, Redhill, on the right side of the river, seems to be just in the district to the south, and so has been described in the Memoir thereon;* another seems to be just within our district, and is thus described by Sir J. Evans:—

"A little lower down the river, and on the same side as Redhill, is the spot to which the name of Whitehill has been given by Mr. Prigg. The gravel is composed of similar materials to that at Redhill . . except that the matrix is whiter. Mr. Prigg informed me that beneath the gravel are beds of red sand, and that at one time a section was exposed of 26 feet in depth. Of late the gravel at this spot has been but little worked, and but few implements have been found in it. . ."

"Remains of *Elephas primigenius* and horse have been found here, but no land or freshwater shells."†

This narrow strip of gravel extends along the eastern side of the river to Two Mile Bottom, with a short spur up the side-valley, toward Croxton, in which Mr. F. J. Bennett noted a pit on the southern side of the track and about a mile westward of Croxton, showing 5 feet of subangular gravel.

On the other side of the river, by Warren House, is a patch of gravel, the remains of a higher terrace, to which probably Sir J. Evans refers when he says that, on the slope of Santon Downham Warren, "towards the river is a considerable expanse of gravelly beds, which have been largely excavated for road-making purposes . . it has produced, at a moderate estimate, upwards of two hundred specimens [of implements], some of them affording the finest instances of the skill of the Palæolithic Period which have been found in Britain, or indeed elsewhere. . . The gravel is at a somewhat higher level above the river than that at Redhill, but resembles it in character. It contains, besides flints, a few of the quartzite pebbles of the New Red Conglomerate, which have been derived from the Glacial beds. . . The gravel is of considerable thickness, so much so that in places, caves of sufficient magnitude to allow of a man standing inside have been formed within it, in consequence of the lower beds being let down into the chalk, through its erosion by water charged with carbonic acid. . ."

"Among the implements from Santon Downham [presumably from this patch] the almond-shaped type seems to predominate."‡

Very likely gravelly soil and pipes of gravel extend some way beyond where it has been thought safe to colour gravel on the map.

Sir J. Evans had previously given a fuller account of the cavities referred to above, an explanation of which will come in more conveniently further on, under Broomhill (see p. 94), as there one was carefully examined. Of those at this site, Sir John's description is as follows§:—

The cavities were first seen by Mr. R. Fitch, of Norwich, and one here "was large enough to allow him to stand inside, a layer of dark clay lined the bottom of the hole, and this formed a basin-shaped floor. Its roof was beautifully rounded and smooth, and had all the appearance of design, and on excavating at the bottom, a flint implement of a Palæolithic type was found."

A little later Sir J. Evans had an opportunity of "inspecting one of the caves, which, however, it was not possible thoroughly to investigate. Only the upper part of the cavity was visible, of a regular vaulted form, the sides being formed of coarse incoherent gravel, while the roof . . consisted of a much finer gravel, with a more coherent matrix of red sand . . there was no opportunity of observing whether there was any sandpipe at the bottom, though no doubt such was the case. In the wall of gravel close by there were two sandpipes in which the upper beds had followed down in the usual manner."

* The Geology of Parts of Cambridgeshire and of Suffolk, pp. 80, 81. (1891.)

† The Ancient Stone Implements . . of Great Britain, pp. 499, 500. 8°. *Lond.*, 1872.

‡ Ancient Stone Implements, pp. 500, 501.

§ *Geol. Mag.*, vol. v. pp. 444, 446. (1868.)

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In the strip on the other (right) side of the river, above and below Santon no section has been noted, though Mr. Skertchly seems to have marked one three quarters of a mile north-westward of the church. Mr. H. Prigg, however, has remarked, "It was at Santon, in . . 1862, that the first flint implement was discovered," in the valley of the Little Ouse.*

On the same side, a little lower down is a patch, which at one part reaches down to the Alluvium, whilst on the west, and to a slight extent on the east, it is separated therefrom by a narrow outcrop of chalk, the gravel reaching up northward to or beyond the railway. This site is well known (as Bromehill, or Broomhill, from the house of that name close to its western end) through its having yielded many implements.

Mr. J. W. Flower first described it, as follows:—"The implements, which are usually much rolled and worn, and are often stained to a chocolate-colour, are here found in a gravel-pit, about 350 feet from the river-bank. They are usually met with in a bed . . resting immediately on the surface of the chalk, and 5 or 6 feet above the level of the river," the section being as below and the total thickness from 25 to 30 feet†:—

Sand, sparingly intermixed with angular flints, of no great size.
Gravel, less ferruginous than that below, but with a greater proportion of broken chalk.
Ferruginous flint gravel, very coarse, not much rolled, with large flint nodules (some weighing over a hundredweight), quartzite pebbles, and rolled fragments of chalk; about 2 feet; resting on chalk.

Sir J. Evans however says that this "description of the section and of the position in which the implements are found, does not completely coincide with mine . . in July, 1868 . . the section exposed was 24 feet in height, from the chalk at its base to the superficial soil at the summit," the beds being as follows:—

Sand, with a few gravelly seams and with a dark ferruginous bed, a few inches thick, at the base; 8 to 10 feet.
Ochreous gravel, with a red sandy matrix; 8 or 9 feet.
Band of grey sand.
Gravel, with a large per-centage of rolled chalk, and seams of chalky sand.
Ferruginous beds sometimes occur below, with large flints.

"In the chalky gravel . . implements are rarely found, but what there are, are usually black . . In the ferruginous gravel [above] they are more abundant, and, as might be expected, ochreous in tint . . There are but few pebbles from the Glacial beds in the gravel."

"Remains of *Elephas primigenius*, and of horse, have been found here. . ."

"In addition to the pit in the bluff facing the river, there is another in the same gravel, but on the other side of the railway, which has been here cut through it. In this also implements have been found."‡

It was at the Broom Hill pit that Sir J. Evans examined one of the cavities already alluded to, under Santon Downham, and the following account is from his paper.§

"The opening into the cavity was not much more than a foot in diameter, and was about the middle of the bed of ochreous gravel [see his section, above]. It was soon sufficiently enlarged to enable one of us to creep in, and by the aid of a candle to examine the cavity. It was slightly irregular in form, and seemed about three feet in diameter [width] and about five feet in height, but we did not take any accurate measurements, as we were in constant fear, and not without reason, of the face of the cliff of

* *Rep. Brit. Assoc.* for 1866, *Sections*, p. 50. (1867.)
† *Quart. Journ. Geol. Soc.*, vol. xxv. p. 449. (1869.)
‡ Ancient Stone Implements, pp. 505–507.
§ *Geol. Mag.*, vol. v. pp. 445–447. Reprinted from *Norfolk News*, 5 Aug. 1868.

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gravel falling in upon us. The bottom of the cavity had some sand upon it, which had fallen from the roof, the cavity extending upwards through the gravel, so that its ceiling was formed by the base of the sands above. The axis of the cavity was not quite perpendicular. Having examined it as far as was consistent with safety, we next commenced cutting a vertical groove in the face of the gravel below, with a view of ascertaining whether, as I had suspected, there was not a sandpipe below, the absorption of the gravel into which was the primary cause of the cavity. The second blow of the pickaxe broke through the wall of gravel and at once revealed a sandpipe, thus proving my view to have been correct."

"We at once proceeded to clear it out as far as was consistent with safety, and found that at about three feet above the base of the gravel the pipe was about two feet in diameter and nearly circular, but whether it descended into the Chalk we were unable to see, and before we left the pit the face of the gravel cliff gave way, and the scene of our operations was buried under a mass many tons in weight." A flint implement "of the pointed form was found under our eyes by one of the workmen among the gravel he was clearing out of the pipe."

"The existence of this sandpipe below the cavity, similar in character to the pipes so frequently occurring in sands and gravels overlying calcareous strata, at once proved that these cavities were of natural and not of artificial origin," [as had been suggested].

Generally such pipes, formed by the irregular dissolving away of chalk beneath other beds, "have been filled by the superincumbent beds gradually following down, but we can readily conceive instances in which some one or other of the upper beds might be so tenacious as not to subside into the hollow beneath until a large superficial area was left unsupported. The result in such a case would be a cavern of greater or less magnitude, from the bottom of which proceeded a pipe passing through calcareous rock, and filled with the remains of the less tenacious beds underlying the more unyielding bed, which would form the ceiling of the cavern. These conditions were fulfilled in the cavity in the Broom Hill Pit, where the tenacious bed was the sand with the compact argillaceous band at its base, the incoherent beds which filled the pipe were the ochreous gravel and sands, and the pipe was eroded through the calcareous gravel, and probably into the Chalk itself."

"I think it must be evident that a cavity large enough 'to hold a cart inside,' eroded by the carbonic acid of vegetable matter decaying on the surface, and carried down by the rain, implies a lapse of time for its erosion such as is quite in accordance with the antiquity which from other considerations must be assigned to these beds, containing as they do the undoubted handiwork of our barbaric forefathers."

Mr. Skertchly has noted (Gun Flint Memoir) that in the large ballast-pit adjoining the railway at Broomhill (the section described above) some very good flint was found, a rather remarkable circumstance, for the flint in gravel is nearly always full of cracks.

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The longest strip of gravel and sand in this valley is on the southern side, from just above Santon Downham to about 1½ miles below Brandon. The following description of sections at its western end are from MR. SKERTCHLY'S notes.

"A pit on the brow of the low hill, south of the railway about 1¼ miles westward of Brandon Station, was about 10 feet deep, in 1875, but much obscured. The section seemed to be as follows:—"

Coarse gravel, chiefly of chalk (some of the fragments a foot across) mostly rounded; the stones jumbled together, on end, etc. Also flints, worn and unworn, greensand (stone), greenstone, quartz, phosphatic nodules, and many pieces of septaria. A small fragment of a Belemnite (? *B. minimus*) was found; 6 feet.
Fine, bedded, red sand; 2 feet.
Bedded, brown loam; seen to 6 inches.

"In another pit, 300 yards to the west there was a good section, 12 feet deep, variable, but taken generally as below, the materials being as in the last:—"

Very sandy soil; 3 feet.
Roughly-false-bedded, fine and coarse chalky gravel; 6 feet.
Fine, light-coloured, false-bedded sand; a foot to 2 feet.
Gravel, like that above; seen to a foot.

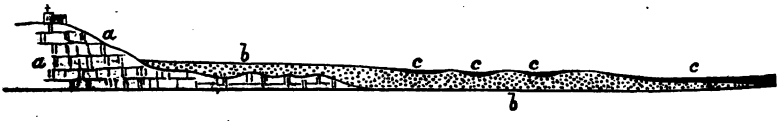
"A small pit, level with the base of this, showed the following beds, fairly evenly and horizontally bedded":—

Comparatively fine gravel; a foot.
Red, false-bedded sand; 6 inches.
Very coarse gravel; 3 feet.

"At the chalk-pit, marked Lime Kiln on the map, by the southern side of the railway 1¾ miles westward of Brandon Station, there is generally no gravel-capping; but in the middle part of the eastern face a basin-shaped mass of gravel, like that in the pits to the east just described, cuts down 15 feet into the chalk, and contains large masses (2 feet square in section) of unworn chalk, and in places seams of fine false-bedded sand. The chalk is white, marly, with here and there a small flint, and evenly and horizontally bedded."

Crossing again to the Norfolk side of river there is a strip of sand from Hockwold westward. Of this MR. SKERTCHLY has said, in the Fen Memoir, that the sand at Hockwold is like that at Beck Row, in the district to the south, with hollows of peat, too small to map and over which the sand has blown in places. The generalised section from north to south is shown in Fig. 21. The sand is fine, varies from white to red, with carbonaceous stains, and includes many small and a few large flints.

FIG. 21. *Section from Hockwold to the Fen.*



a. Lower Chalk. *b*. Sand. *c*. Peat.

W.S.W. of Hockwold a small island is barely separated from a spur of this sheet.

Beyond this the fen hides everything, except for the small gravel island of Shrub Hill, about four miles west of Hockwold, which is noted for yielding flint implements. This seems to have been first noticed by MR. H. PRIGG, who says:—"Dividing it obliquely from N.E. to S.W., the northern part consists of coarse subangular flint gravel in a sandy matrix, with underlying

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beds of greyish sand, while the lower or southern portion has for its base an outcropping bed of fine Gault, with layers of the marine fossils."*

Mr. J. W. Flower has added the following particulars:—"This bed [of gravel], which is now extensively worked, was until lately quite unknown, the gault and the gravel being alike effectually concealed by the great bed of peat which just covers them." [?] . .

"The gravel here is about 12 feet in thickness, but at the surface it is only 6 feet above the river. The implements . . are, with very few exceptions, found at the bottom of the gravel, and not seldom they are lying upon the surface of the gault; they are usually much worn and rolled, and occur in considerable numbers: the gravel here is unstratified, and contains much less quartzite than at Brandon [Gravel Hill], and the overlying [Mr. Prigg says underlying] sands do not attain so great a thickness."

"One implement . . which was found on the surface of the gault, is probably the largest yet discovered . . it is 11½ inches long, and its circumference at the thickest part is 13 inches."

The only fossils recorded are "some fragments of the horns of deer, and teeth of some ruminant, probably deer also, as well as some teeth of a small species of horse, all much broken and rolled."†

Sir J. Evans seems to have quoted *Elephas primigenius* from here by mistake. He noted of the gravel that "the thickness varies, being often less than 8 feet. . . The gravel consists mainly of subangular flints, with some rolled chalk and a considerable number of quartzite pebbles, and rolled fragments of other old rocks, derived from the Glacial Beds higher up the river." The sandy matrix is "more or less ochreous at different spots. . . The implements . . have been found in considerable numbers, and of various types, including many flakes." The large implement alluded to by Mr. Flower was given by him to the Christy collection.‡

Valley of the Wissey.

There are but few and slight traces of River Drift along the course of the Wissey, until it enters the Fens, at Stoke Ferry; less indeed than along the courses of the tributaries, on the north, in only one part of which however is there a spread of much extent, at Shingham.

Mr. Hawkins says that "about a furlong E. of Wellmere Plantation, N. of Shingham, a small pit showed 3 feet of sandy gravel, composed for the most part of angular flints."

Mr. Cameron has mapped three gravel-islands in Methwold Fen, of which he says: "Sluiceholme and Calsholme Hills are wholly gravel, except for a patch of bare Chalk at the southern end of the former. There are several shallow old pits in a somewhat clayey gravel, with pockets or lenticular masses of sandy loam. The stones are mostly local, flints and chalk, with some quartzite and sandstone. On this gravel-land rude flint implements have been found."

From Stoke Ferry to Wereham Fen there is a large spread of sand and gravel, but it was without sections of note.

Westward of Stoke Ferry Station the sand is gravelly, and before reaching the station peat comes on, and has been found to the depth of 17½ feet.

Along the railway westward of Wretton there is mostly sand, with clay coming up from beneath, and this latter gets white and more calcareous eastward.

A very slight attempt at a cutting on the railway S.E. of Dereham Abbey showed very little chalky gravel, perhaps a foot thick, on clay.

A little east of Abbey Station (West Dereham), in a smaller sheet separated from the larger spread by Alluvium, the ditch, by the side of the railway, is in

* *Quart. Journ. Suff. Inst.*, vol. i., no. i., p. 4. (1869.) Read Sept. 1866.

† *Quart. Journ. Geol. Soc.*, vol. xxv. pp. 451, 452. (1869.)

‡ The Ancient Stone Implements of Great Britain, pp. 513, 514. 1872

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very thin peat over light-grey clay. Further on gravel comes on, under the clay (which ends off) apparently. As however some of the clay contains Belemnites and phosphatic nodules it would seem to be Gault, reconstructed.

Valley of the Nar.

In the higher and narrower part of this valley, above Narford, there are but a few small patches that can be referred to River Drift; but in the lower and broader part there are considerable sheets, which, like the Nar Clay, reach across the low ground into other valleys, as described below.

As Mr. Hawkins says, of the upper part of the valley, "it is possible that on the map some gravel of more recent age may have been included with the Glacial gravel, owing to the difficulty of distinguishing between them when occurring together. At and below Narford however the low level gravel may be safely classed as Post-Glacial, for it overlies the Nar clay in places." The following notes are by this observer :—

"At Newton a little gravel, between the church and the stream, may be Post-Glacial."

"Three eighths of a mile S.W. of the church there is a little sandy gravel, perhaps also Post-Glacial, and on the opposite, or right, bank of the stream there may be a little River Gravel." None of these however have been separated from the older gravel, for want of evidence.

"Near the bridge at Castle Acre there seems to be a little River Gravel on either side of the stream; and there is also some at the bend W. of the Priory Ruins."

"At South Acre some gravel, at a low level, spreads round the Church and down to the Alluvium."

"At the brickyard about half way between this and West Acre some gravel, bordering the Alluvium, may also be of this age."

"At Narford this gravel begins, on the southern side of the river, about half a mile above the bridge, and runs for about 1½ miles toward Narborough, when there is a short gap, E. of the Hall; but sandy gravel comes on again at the Hall and may be traced for 2½ miles south-westward, until it disappears beneath the Fen northward of Marham. The southern boundary of this patch is very doubtful, especially at the south-western end. A pit in the eastern fork of the roads S. of Narborough Hall showed a thickness of 5 or 6 feet of gravelly sand, with chalk beneath."

"At Shouldham Warren there is a small patch of gravel on the hill-top; but this is doubtfully classed as River Gravel. It has been largely dug, but the pits were obscured and overgrown with trees. It seems to be of a loose sandy nature, and is described by men who used to work it as 'siftings.' Small flints and a few quartz pebbles may be seen on the surface."

"The northern part of Wormegay island is almost wholly covered by flint-gravel, and sand. At the north-eastern corner a pit showed 5 feet of sandy gravel overlying clay, probably Boulder Clay. Gravel may be seen at the corner of the roads, a quarter of a mile N.W. of Park Farm, and near the north-western end of the island an excavation by the side of the main drain showed 6 feet of it."

"On the road N.N.W. of Tottenhill church there is an old gravel-pit, now much hidden. The boundary of this patch is doubtful toward the south, in which direction it may reach further than has been mapped; and the age of the gravel is doubtful also."

Turning now to the northern side of the valley, where it widens out, the gravel and sand, like the Nar Clay (see pp. 84, 89), stretch irregularly across the tributary-valley that runs from East

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Walton by Pentney, and thence across the larger tributary, the Gaytonthorpe Valley, into the now independent valley of the Middleton Drain. The result is that islands of Cretaceous beds are left (Pentney, West Bilney, etc.) surrounded by gravel, or in part by Alluvium, the much larger mass of Middleton, etc. being another like island. It is difficult therefore here to assign the gravel to particular valleys.

Mr. Hawkins notes that "flinty gravel, of a loose sandy nature, may be seen all along the northern side of the stream from Narford to Narborough: at Narborough Station it has been dug, by the side of the railway."

The railway-cutting S.E. of the former Bilney Station, which was on the high road east of the church, is turfed over; but the ditch is in chalky Gault all along. At the higher part there seems to be sand at top; but this must be thin. At one place there is a trace of clay above the chalky earth.

Gaytonthorpe Valley.

Mr. Hawkins remarks that the upper part of this valley "contains an interesting set of deposits, from a little below the Peddar Way some 3½ miles south-eastward to below Gaytonthorpe." Their interest is largely owing to clear evidence of freshwater origin, in part, and to the fact that they were described many years ago, by that careful observer Mr. J. Trimmer, in whose time there would seem to have been better sections than those seen by Mr. Hawkins. He first published an account of this Drift in 1847,* in which he says: "From the numerous fragments of a very thin univalve in the calcareous sand [Fig. 23], accompanied by horny *opercula*, resembling those of a small *paludina* [*Bithynia*], and from part of a *unio* occurring in one of the beds of clay, I was satisfied that they were freshwater deposits. The specimens which I procured were too imperfect to enable me to obtain an opinion on them from an eminent naturalist; but Mr. Rose . . has recently set the question at rest by the discovery of several entire specimens of *cyclas* and one *planorbis* . . there can be no mistake about the presence of these freshwater genera."

In a later paper† Mr. Trimmer reproduced the above, gave some further details (which will be used further on), and said that the valley "is filled with deposits, the variable character of which is shown in the several marl and clay pits opened along its course," having before remarked, "The most remarkable feature of these deposits is, that, amidst a general absence of organic remains, one of the sections exhibits freshwater strata with mammalian teeth, resting on a variety of the boulder clay; and that pipes and furrows have been found in the freshwater deposits, similar to those in the chalk."

Mr. S. V. Wood, Junr., in reproducing one of Mr. Trimmer's sections (Fig. 23, p. 102), agreed with that author in thinking that "the beds *d*, *e*, and *f* . . are . . a freshwater continuation, at proportionally higher level, of the Nar brickearth; and

* *Journ. R. Agric. Soc.*, vol. vii., pt. ii., pp. 471, 472, 485.
† *Quart. Journ. Geol. Soc.*, vol. vii. pp. 23, 26–29. (1851.)

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therefore . . of the age of the *Cyrena*-formation,"* as also the March gravel (see p. 107).

Mr. Hawkins, who mapped this part, says: "A sandy fresh-water marl may be traced for about two miles down the valley, from about a quarter of a mile westward of the Peddar Way. This marl is not confined to the bottom of the valley, but spreads a little way up the sides, sometimes forming esker-like mounds, and it is of considerable thickness. It is very difficult to determine the boundaries, and the marl may possibly occur here and there beyond the limits assigned to it on the map; perhaps too it may fill the bottom of the valley up to the Peddar Way. Mr. Trimmer was mistaken in saying that 'in about five chains more [above the highest marl-pit, first to be described] these deposits cease.'"

"The marl-pits begin a mile westward of the Peddar Way, where there is one on the northern side of the road and at the eastern end of an esker-like ridge, with the following section:—"

Laminated marl, varying from nearly white to bright orange, with small fragments of chalk and a few flints scattered throughout, and with opercula of a gasteropod and freshwater shells; about 7 feet.

Fine flinty chalky gravel, just shown beneath, all below this being hidden by talus.

"The distinct planes of bedding show a dip apparently toward the bottom of the valley."

This may be one of the pits which Mr. Trimmer figured, and, as his figure shows more than was seen by Mr. Hawkins, it is reproduced (Fig. 22). The latter thinks however that the most easterly pit did not exist in Trimmer's days. Continuing from Mr. Hawkins' notes:—

"The next pit is about a third of a mile further down the valley, on the same side of the road, and seems to be about 20 feet deep; but there is water in the bottom, and, except for from 5 to 7 feet at top, all was hidden by talus. There is a brown sandy soil, with flints, to a depth of from a foot to 2 feet, and below this, with a junction made very uneven by pipes, chalky clayey sand, with angular and unworn flints scattered through it. This was seen to the depth of 5 feet from the surface on the western side of the pit: on the eastern side it passes down into soft marly finely-laminated sand, which seems to be less marly lower down." The above seems to refer to the pit of which Trimmer says "the nature of the deposits cannot be made out."

The next pit, Mr. Hawkins says, is "on the southern side of the road, about a third of a mile lower down (just halfway from the Peddar Way to Gaytonthorpe church), and it showed nearly 25 feet of buff marly sand, very compact in the upper part; with traces of bedding and, in one place, of false-bedding, marked by seams of fine gravel, consisting of flints and chalk pebbles. This is overlain by soft brown sand, often in pipes several feet deep, the upper part of which contains angular flints." Presumably the brown sand is the result of the decalcification of the marly sand. Mr. Hawkins adds that "on washing some of this marly sand, the residue, when examined under the microscope, is found to consist largely of the spicules of sponges, of foraminifera and of other organic remains commonly found in Chalk, with a certain proportion of quartz grains."

Mr. Trimmer makes this pit somewhat deeper, and divides the sand as follows:—

Sand and clayey sand, the obscure lamination transverse to the direction of the valley, with seams of chalk pebbles and fine chalk detritus; the upper 4 or 5 feet more calcareous than the rest; 15 feet.

More clayey and less laminated sand, with pebbles of chalk dispersed throughout; 12 feet.

Sand below apparently.

* *Quart. Journ. Geol. Soc.*, vol. xxxviii. p. 722. (1882.)

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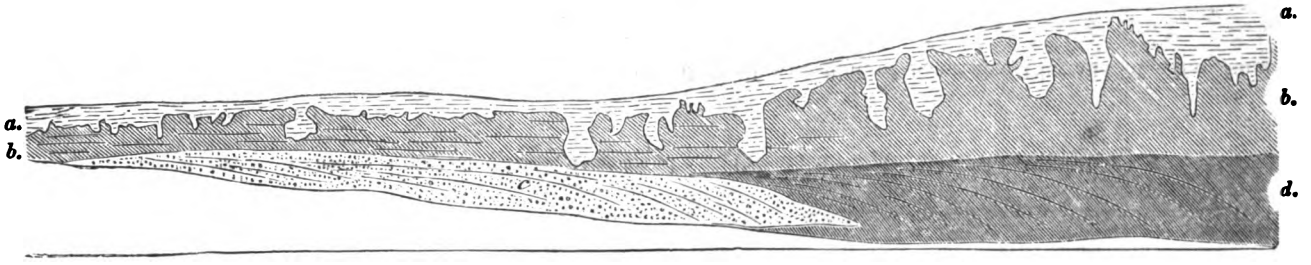
FIG. 22. *Section in the Valley above Gaytonthorpe.* (J. TRIMMER.)

For this and the following figure we are indebted to the kindness of the Council of the Geological Society.

E. (Scale, 10 feet to an inch.) W.



a. **Warp or soil.** Fine ferruginous sand, with scattered angular **flints; filling pipes and furrows in** *b*.
b. **Marl, slightly** laminated horizontally. **Passes, in about 20 yards, into a nearly unlaminated mass.**
c. Gravel, of small **flints, rounded and angular;** false-bedded, **resting apparently** on clay like *d*; but the base of the pit hidden by débris, etc.
d. Grey and yellow **clay, obliquely laminated, the laminations from** $\frac{1}{8}$ **to** $\frac{1}{2}$ **inch thick;** with some seams of ferruginous sand, and false-bedding. [? Glacial Drift.]

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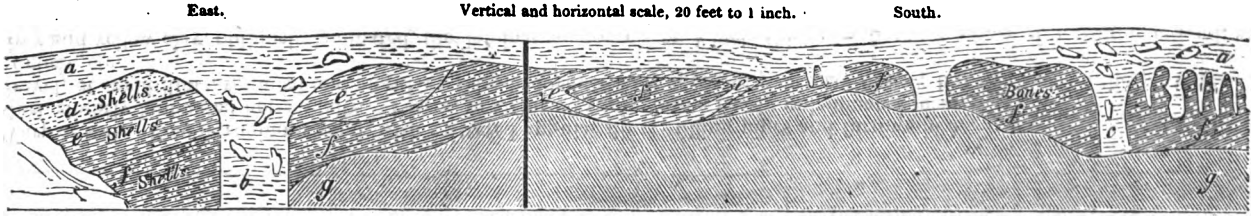
FIG. 23. *Section in the Valley above Gaytonthorpe.* (J. TRIMMER.)

This appears also, in outline, in the earlier paper, in *Journ. R. Agric. Soc.*



a. Warp. Sandy loam; with unworn flints, some large, as at *b* and *c*. [Presumably a product of decalcification.]

Freshwater beds. *d*. White calcareous sand. *e*. Grey and yellow silt. *f*. Grey clay.

g. Drift, like the most chalky varieties of the Till; with fragments of Chalk-with-flint, of Kimeridge Clay and of other Jurassic rocks. [Boulder Clay.]

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Just within the eastern edge of the plantation, as marked on the map, between the fork of the roads and less than 1¼ miles from Gaytonthorpe church, is the old pit, of which TRIMMER gives the following section :—*

Sandy loam, with many large flints, not quite so large as those in the gravel-pit to the west (most quite sharp, but a few slightly waterworn); a foot to 4 feet, varying with the depth of the furrows and pipes in the underlying

Cream-coloured marl, coarsely laminated, with oblique bedding transverse to the direction of the valley; some seams of sand and of chalk pebbles; on the northern side alternates with dark clay; about 12 feet.

Before MR. HAWKINS was there this pit must have been dug further westward and the gravel-pit further eastward, for he notes them as a much less distance apart than the six chains allowed by TRIMMER, and he notes also the occurrence of a thin gravel above the buff marl. He adds, "the pit, which is reported to be very deep, holds water, and the bottom of the pond may be in Boulder Clay, as fragments of chalk can be seen at the level of the water, or about 10 feet below the surface of the ground." These however may be the chalk pebbles of the earlier account.

The gravel in the pit just west was described by TRIMMER as "worked to the depth of four or five feet, consisting of coarse chalk flints, very few of them at all abraded,"† and MR. HAWKINS' much later note is practically identical.

About an eighth of a mile below the fork of the roads, and on the southern side of the road, MR. HAWKINS noted that "light-coloured sandy marl is ploughed up by the side of an old pit, which has been partly filled in and no longer shows any section." This is all that remains of the fine exposure twice described and figured by Trimmer,‡ (see Fig. 23, p. 102), who says, "From the spot where the word 'Bones' occurs [see Fig.], Mr. Rose has obtained a nearly complete set of the teeth of the lower jaw of a species of *Bos*." His remarks on the shells found have already been given, on p. 100, from the earlier paper, the wording of which is not exactly followed in the extract therefrom in the later one.

He also noted a pit, a little lower down the valley, on the northern side of the road, as "full of water, but reported to have exhibited, where worked, the same characters as" the section at the Gaytonthorpe brickyard. This would seem to be the "round pond" noted by MR. HAWKINS as "nearly south of the 33 mile-stone on the main road, said to be of great depth, and of which the sides seem to be nearly vertical. It is full of water, and even overflows sometimes. Below this the southern edge of the clay is hidden by gravel, down to the farm, for about three eighths of a mile."

MR. HAWKINS says that "at the brickyard, about a third of a mile northward of Gaytonthorpe church, bluish-grey clay is dug to a depth of 9 feet, is of a dark slate-colour, and quite free from pieces of chalk and flints; neither does it contain any fossils. On washing a sample, the residue, when examined under the microscope, was found to consist of minute crystals of selenite. The pond close to the farm, about a quarter of a mile eastward, shows similar clay."

It is a little doubtful whether TRIMMER'S note refers to the same section, as he says that the "bed of blue clay, opened to the depth of about 12 feet . . . contains some small pebbles of chalk;"§ but such beds are liable to change, and the part of the clay with chalk pebbles may have been worked out in the interval of more than 30 years.

The REV. G. B. MOXON, in saying "the Gayton brick-pit has been sunk down upon the chalk,"‖ presumably refer to this, the only brickyard near.

MR. HAWKINS again says that "the patch of Boulder Clay west of the village seems to be overlain by clay, which is free from chalk, and may either be a brickearth of Glacial age, or perhaps a continuation of that in the brickyard." The latter view has been taken on the map, with the advantage of simplicity.

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* *Quart. Journ. Geol. Soc.*, vol. vii. pp. 27, 29.

† *Ibid.*, p. 27.

‡ *Journ. R. Agric. Soc.*, vol. vii. pp. 471, 485, and *Quart. Journ. Geol. Soc.*, vol. vii. pp. 27, 28. (1847, 1851.)

§ *Quart. Journ. Geol. Soc.*, vol. vii. p. 27. (1851.)

‖ *Proc. Sci. Soc. Lond.*, vol. ii. p. 64. (1840.)

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Mr. Hawkins writes of this upper part of the Gaytonthorpe Valley, "The deposits here may perhaps be explained somewhat as follows:—Toward the close of the Glacial Period, or during an interval in that period, the valley was occupied by a stream, which drained the adjacent country. This stream, which would bring down the débris both of the Chalk and of the Boulder Clay, deposited the heavier particles of chalk and of sand in the upper part of its course, while the finer material, derived from the Boulder Clay, would be carried further and deposited lower down, where the velocity of the water would have decreased, either from the stream expanding in the wider part of the valley, or from its meeting some obstruction, such as the low hill of gravel previously mentioned (p. 77). Thus the lower part of the channel might get silted up, and a lake formed, in which the deposit of materials brought down by the stream would continually increase and extend higher and higher up the valley. This explanation presupposes the existence of the valley during the Glacial Period, and that this was the case seems to be shown by the occurrence of Boulder Clay in the valley at Gaytonthorpe." The occurrence of esker-like gravel in the top part of the valley (see p. 77) may support this conclusion; but I am not sure that it is essential to Mr. Hawkins' explanation. A mass of Boulder Clay, at Gaytonthorpe, may well have served as a dam, suffering somewhat less from erosion, in Post-Glacial times, than the Chalk of the valley above suffered from dissolution. From this Chalk probably powerful springs issued.

When this valley broadens out, below Gaytonthorpe, it is sometimes difficult to refer the gravel to a particular valley, as has been already noticed (pp. 98, 99), because the gravel stretches across from valley to valley.

Mr. Kent told me that at the Hall, about half a mile E. of S. from East Winch Station, he had put down a tube-well, in the field just at the back of the house, which did not reach clay until nearly 40 feet of sand had been passed through, and that another well, to the south, passed through 23 feet of sand.

South-westward from East Winch is a curved line of gravel-patches, all but one very small. In the first three (the smallest) no section was seen; but in the fourth a pit near the top of the hill, and nearly a mile from the church, showed, in 1883, a thickness of about 10 feet of gravel, sandy, mostly coarse, chiefly made up of rolled flints, but in part chiefly of broken-up carstone, with a good deal of ironstone. Large blocks, sometimes indeed short layers, of carstone also occurred in the flinty part, and also some irregular sandy layers, apparently derived from the ferruginous sand of the Lower Greensand. Pebbles of quartz were very rare.

In the furthest and largest patch an old pit is marked on the map, toward the north-eastern end, and a very large one was open at the time of my visit in the central part. This showed in parts a thickness of as much as 12 feet of gravel and sand, but of nearly 20 feet on the south. The lower gravel here is finer, being made up of small flints, and on the whole the gravel is not so coarse as in the pit above noted, containing a thicker bed (or thicker beds) of sand, but none of the carstone-blocks. The absence of the blocks here may be owing to this part of the gravel being further from the carstone-cliff against which the gravel presumably abutted.

From the composition of this gravel, which is practically of Cretaceous derivation, and from the way it lies on the flank of the hill, one would infer that it is not Glacial; but of quite local origin, formed perhaps by a river, at a time when the Chalk extended further westward.

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CHAPTER 12. POST-GLACIAL DRIFT.

Marine Gravel.

General Note and Literature.

The gravel now to be described is of interest from the occurrence in it of marine shells, sometimes in great plenty; so much so indeed as to give it the look of a shelly Crag, from which however it differs in the species of its shells. It occurs chiefly on islands in the Fens, in the south-western part of our district, and also in the tract to the west, and, like the other gravels that have been noticed, its chief constituent is flint. The chief tract is on the large island of March, and it is to this that the literature mainly refers.

The earliest account is by Prof. H. G. Seeley, in two papers published in 1866,* in the first of which he describes a pit at March, presumably near the railway-station, the exact place not being stated, as giving "a section 150 yards long, displaying a gravel included in the Boulder-clay. The gravel was thin, a foot or so, though thicker east and west, and overlain . . by clay containing characteristic specimens of Septaria striated by drifting, hard chalk, often grooved as though by ice, and one bough of a tree some 3 inches in diameter, converted into imperfect lignite." In the reference to the figure however this bed is described as "Boulder-clay, not very characteristic." He continues:—"The gravel, which was largely made up of small pieces of flint and of sand, contains an abundance of comminuted shells and many whole ones, *Tellina* and *Turritella* being commonest. The Boulder-clay, where seen underneath, has the usual characters."

It is not easy however to compare the descriptive text and the account of the figured section, the latter of which shows yet another Boulder Clay, in the shape of a thin layer in the lower part of the gravel. A list of 21 species of shells is given.

In his more theoretical second paper Prof. Seeley speaks of this gravel as "contained between Boulder-clays, and obscure in age," and he regards it "as the oldest of the Fen gravels," adding that it "perhaps corresponds to the contorted drift," or, in other words, may be of Lower Glacial age, a conclusion which need by no means follow, even if the gravel should be found to be capped by undoubted Boulder Clay. Of the shells he says: "Judging from their arctic aspect they might belong to the Boulder-clay age, but the Wash would be a very likely place to cut off and retain a retreating colony."

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* *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 472, 473, 480; and *Geol. Mag.*, vol. iii. pp. 500, 501.

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The next notice is by MESSRS. S. V. WOOD, Jun., and F. W. HARMER,* who clearly do not accept the overlying earth as Boulder Clay, as they say of the March gravel that "there are no means of testing geologically its position," and of its shells that they consist "entirely of species now living, and which, with two exceptions, still inhabit British seas . . *Ostrea edulis*, which is absent from all . . the English glacial beds, is abundant." This does not accord with the "arctic aspect" of PROF. SEELEY, and the authors conclude that the beds "belong to the earlier, or *Cyrena fluminalis* part of the Post-glacial period." The list of shells (at the end of the vol., in 1874,) is extended, by MR. S. V. WOOD the elder, to 30 or 31 species.

In 1875 these deposits were twice noticed. PROF. JUDD, in a Geological Survey Memoir, descriptive of the district to the west of that now in question, classed the "Marine Gravels of the Fenland" as Post-Glacial, and said that they "evidently formed beaches surrounding the old sea which once covered the Fenland."†

PROF. BONNEY also said:—"The [March] gravel is variable in thickness and in character, shows false bedding, and is sandy in places, especially at the base," and:—"It certainly appeared to me that . . the upper clay at March was not true Boulder Clay, so that, regarding also the physical geography of the district, I am disposed to adopt Mr. Searles Wood's opinion."‡

In 1877 MR. SKERTCHLY described the whole of this gravel, in detail, in a Geological Survey Memoir,§ giving a list of 34 shells, on the authority of MR. F. W. HARMER.

He speaks of it as being "The remains of old valley gravels, usually fossiliferous, and probably of interglacial age;" but this hardly accords with the following quotation (in so far as Interglacial beds must be of Glacial age) in which, speaking of the Boulder Clay cited by PROF. SEELEY as above the gravel, he says: "I cannot but think this must have been merely a patch of detritus, and much more powerful evidence is certainly required to establish so unique a phenomenon as a boulder clay above the fen gravels. Mr. Seeley also cites a thin bed of boulder clay intercalated towards the base of the gravels. This certainly no longer exists at the spot or anywhere in the neighbourhood, and cannot have been other than an isolated patch which is not proved to have been *in situ*. Finally, then, we must conclude that this attempt to show the glacial age of the March gravels has utterly failed. It is in every respect similar to the other fossiliferous gravels of the fens, and, like them, newer than the glacial clays of the district."

Presumably the author's meaning is that though the March gravel is newer than any Glacial bed in the district, yet it may

* Supplement to the Monograph of the Crag Mollusca, Part I. pp. xxviii., xxix. (1872.)

† The Geology of Rutland . . p. 251.

‡ Cambridgeshire Geology, pp. 56, 57. (1875.)

§ The Geology of the Fenland, pp. 183, 187–193, 201, 202, 268.

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be older than other Glacial beds elsewhere (to the north). This of course leaves it open to PROF. SEELEY to say that the clay noticed by him above the gravel may represent one of these newer Glacial beds. It is a case showing the inconvenient nature of such terms as Glacial, Inter-glacial, and Post-glacial when it is attempted to use them as strict time-markers.

MR. SKERTCHLY again alluded to this gravel in the following year.*

In the same year MR. JUKES-BROWNE treated of the March gravels, under the head "Valley Gravels of the Early River System,"† and says from a visit, in 1872, to the section described by Prof. Seeley: "The uppermost clay was certainly not Boulder Clay," describing it as a brownish clay, and noting a somewhat similar bed (yellowish loamy clay) above the gravel in another section. He regards the gravel as Post-Glacial and gives a list of 40 shells from it.

In 1879 MR. S. V. WOOD made a slight addition to the list of shells from the March gravel.‡ The last reference I have found is by MR. S. V. WOOD, Junr.,§ who refers this gravel as well as the Nar Clay (see p. 83), to his "*Cyrena*-formation," which he claims as belonging to the "Post-glacial Period," though overlain, in places, by the "Hessle clay," a later Boulder Clay. This view therefore accords practically with that of MR. SKERTCHLY.

In 1885 MR. C. REID compared the fauna of this gravel with that of the Holderness Drift, concluding, from the similarity of the two, that MR. WOOD was probably right in correlating the two deposits, and gave a more complete revised list of the fossils.‖

Details.

Ramsey.—The northern end of this patch of gravel is in our district, and the following note, by MR. SKERTCHLY, has been adapted, from the Fenland Memoir:—Half a mile south of the Forty Foot Bridge there are many old gravel-pits. The gravel contains a larger percentage of flints and chalk-stones than is usual on the Lincolnshire border. At the great Gault Hole Pits, close to the Forty Foot Bridge, the gravel was seen to a depth of six feet, over Oxford Clay which was dug to a depth of 40 feet.

A note on MR. SKERTCHLY'S map probably refers to this section (E. of the Bridge) and makes the gravel in pockets, with traces of peat running up on to the higher land.

Eastrey.—The larger part of this mass is also in our district, and again MR. SKERTCHLY'S published description is used.

The gravel can be well seen at Coates and Eldernell, but shells are rare. Contortion is not so marked as round Whittlesey and is often absent. In a large pit half a mile west of Eldernell the lie of the beds was well shown in 1870 to the depth of 7 feet. The gravel is beautifully and evenly stratified, and the materials, which vary from fine sand to coarse gravel, with pebbles three inches in diameter, are sorted according to size. They are the same as is usual in fen-gravels, being for the most part Oolite limestone and ironstone, with many flints and a fair quantity of pebbles of older rocks, such as quartzite and Coal Measure sandstone. Some of the beds are stained a rich brown with

* The Fenland Past and Present, pp. 538–540. (1878.)
† The Post-Tertiary Deposits of Cambridgeshire, pp. 58–60. (1878.)
‡ Second Supplement to the Crag Mollusca, p. 53.
§ *Quart. Journ. Geol. Soc.*, vol. xxxviii. pp. 692, etc. see 698. (1882.)
‖ Memoirs of the Geological Survey. The Geology of Holderness, pp. 68–71.

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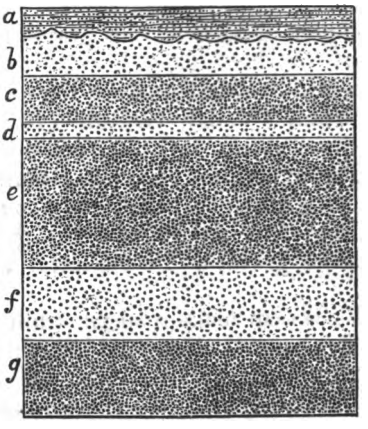
oxide of iron, but this action seems to have been simultaneous with the deposition of the beds, as almost white layers alternate with the brown beds, giving the section a beautiful banded appearance. See Fig. 24.

FIG. 24. *Section in a Pit at Eldernell, Eastrey.*



a. Soil with pebbles.
b. Fine white sand.
c. Fine brown gravel.
d. Fine white gravel, without sand.
e. Coarse brown gravel, finer at base.
f. White gravel and sand.
g. Fine brown gravel.

The beds are not fossiliferous at this spot, but near the South Bank, a quarter of a mile to the east, shells are very abundant, though only seven of the species in the list on pp. 110, 111, were found.

A section of the South Bank is given as:—

Peat, 1½ feet.
Gravel, sandy at the base, 3 feet.
Oxford Clay, seen to 2 feet.

Chatteris.—Near here three patches of gravel have been mapped by MR. REID, a small one on the spur northward of the village, a larger one stretching southward from the village into the district to the south (51, N.W.), and another small one on Langwood Hill, a separate island to the east. He remarks: "The gravel seems always to rest on Kimeridge Clay. No fossiliferous sections were seen (1884)."

MR. JUKES-BROWNE says: "Small excavations in the Nursery gardens near the Station showed 4 or 5 feet of gravel . . banked up against a clayey loam; I was informed that the whole deposit was from 5 to 7 feet deep . . The clayey loam occurs in patches among the gravel . . I could discover no shells, but Mr. Skertchly informs me that *Cyrena fluminalis* has been found here together with *Cardium edule* and *Tellina solidula* (*balthica*)."* This last remark however may refer to the patch of Chatteris Common, north-eastward.

The unnamed island from Horseway to Honey, north-eastward of the village and bordering Chatteris Common, seems to consist of gravel alone, at the surface, and it is this mass only that bears out MR. SKERTCHLY'S remark that "the gravel of the . . Chatteris islands . . descends into the fens." (Fenland Memoir, p. 192.) Shells have been got here.

March.

Of the many patches of gravel over this island, which is nearly seven miles long, from north to south, the main one was mapped

* The Post-Tertiary Deposits of Cambridgeshire, p. 59. (1878.)

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chiefly by myself, in 1884 (from the town northward) as well as that just N.E.; the small patches at the northern end, except that by the 80th milestone on the Wisbech Road, were mapped, at a much earlier date, by MR. SKERTCHLY; and the rest late in 1884, by MR. C. REID, who also visited all the sections.

MR. REID remarks that "the gravel at Doddington has overlapped the Boulder Clay and rests on the Kimeridge Clay. The high-lying patches here seem to be thoroughly decalcified and unfossiliferous, sections west of the village [in the larger mass at Doddington Mill Field] showing merely ferruginous sub-angular gravel."

Of the patch by Wimblington Railway Station PROF. SEELEY says that the deposit, "only a foot or two thick, rests on one of those thin stonebands so common between the Oxford and Kimeridge Clays. It is a fine sandy gravel with the usual shells; but the argillaceous-looking rock was drilled with the burrows of *Pholades*, the shells still being in the holes."* The pit was closed some years later.

Another outlier occurs on the Boulder Clay just north of Wimblington.

In the long mass that reaches from March Church northward, through the town, to Norwood Common, various sections have been noticed. MR. REID noted that "in a small pit just outside the churchyard, 4 feet of soil and made ground was seen over very shelly gravel (with 6 species of shells), to a depth of 3 feet, when apparently the Boulder Clay was nearly touched."

A little gravel was seen, over clay, on the western side of the high road about half a mile northward of the church, and the gravel has been worked to the east.

Shelly gravel occurs nearly half a mile northward, on the road to Upwell End.

The section described by PROF. SEELEY has been noticed above, p. 106, and the sections of two brickyards, by MR. SKERTCHLY, on p. 8.

MR. REID says that "Several pits have been worked at different times near the Railway Station; but the only one open late in 1884 was a little west of Estopher Farm and close to the railway to Wisbech, where a very shelly gravelly sand has been dug to the depth of nearly 12 feet, below which water stops the working." Early in the year before, I had noted that at one part where the gravel was then being worked, about a quarter of a mile N.W. of the Station, there seemed to be bits of Boulder Clay over it; these perhaps were of artificial origin.

MR. JUKES-BROWNE says: "About half a mile north of the Station are . . excavations, showing fine gravels and sands full of marine shells; they are overlaid near the railway by a bed of yellowish loamy clay, somewhat similar to that mistaken for Glacial Clay by Prof. Seeley and possibly once continuous with that deposit."†

MR. REID saw a pit opened in the small patch on the Wisbech Road, close to the 80th milestone.

A Boulder Clay section on the western side of the railway half a mile south of Norwood House showed a little gravel at the top, at the highest part, and pipes of the same further north; but this gravel was unmappable.

MR. REID notes that "just south of Greenford Toll Bar a small pit was opened, to supply sand during the building of a new house, and showed 3 feet of shelly gravelly sand over chalky Boulder Clay. The shells found were *Corbicula fluminalis* and 13 other species given in the list on pp. 110, 111. The large pit opposite was wholly overgrown."

On the Boulder Clay south-eastward of March Railway Station there is a little patchy gravel beyond where it has been mapped.

At the northern end of the mass east of Norwood Common, which is barely divided from the March mass on the S.W., I saw a little gravel over Boulder

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* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 473. (1866.)

† The Post-Tertiary Deposits of Cambridgeshire, p. 59. (1878.)

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Clay at the sharp bend in the road; and there is an old gravel-pit a little S.W.

Mr. Reid notes shelly gravel in ditches a mile north-eastward of the railway-station. It should be understood that great changes have been made in this station since most of the above notes were taken.

Fossils.

The list of fossils has been revised by Mr. G. Sharman, Mr. E. T. Newton, and Mr. C. Reid, the last of whom has added to the species, and who says: "Drift wood is occasionally found, and shells are very abundant, especially the forms belonging to a depth of 5 or 10 fathoms; *Buccinum undatum, Ostrea edulis, Cardium edule, Turritella terebra,* and *Trophon clathratus* are the most plentiful, though mixed with the marine species there a few freshwater forms. Of the four freshwater-shells, only one, *Corbicula fluminalis,* is represented by more than one specimen, and purely littoral forms, that is those living between tide-marks, are generally broken and worn."

H = Harmer, R = Reid (before names).
C = Chatteris, D = Doddington, E = Eastrey (Eldernell) (after names).
All the species have been found at March.

R	Balanus porcatus, *Da Costa.*			
H R	Rhynchonella psittacea, *Chemn.*			
R	? Anomia ephippium, *Linn.*			
H R	Astarte borealis, *Chemn.* and striated var.			
H	„ compressa, *Mont.* - -	C		
H	„ sulcata, *Da Costa.*			
H R	Cardium edule, *Linn.* - -	C	D	E
H R	Corbicula fluminalis, *Müll.* - -	C		
H R	Corbula gibba, *Olivi* (= C. striata and nucleus) - - -	C		
H	Cyprina islandica, *Linn.* - -		D	
H R	Mactra solida, *Linn.* (= M. ovalis, *Sow.* and solidula) - -	C		
H	Mya arenaria, *Linn.*			
H R	„ truncata, *Linn.* - -		D	
H R	Mytilus edulis, *Linn.* - -	C	D	E
H	„ modiolus, *Linn.*			
H R	Ostrea edulis, *Linn.* - -		D	E
H R	Pholas crispata, *Linn.*			
R	„ dactylus ?, *Linn.*			
H R	Scrobicularia plana, *Da Costa* (= S. piperata, *Bellon.*)			
H R	Tellina balthica, *Linn.* - -	C	D	E
H. and Camb. Mus.	„ calcaria, *Chemn.* (= T. lata *Gmel*).			
R	Unio tumidus, *Retzius.*			
H R	Aporrhais pespelicani, *Linn.*			
H R	Buccinum undatum, *Linn.* - -		D	
R	Bythinia tentaculata, *Linn.*			
R	Dentalium entalis, *Linn.*			
R	Emarginula fissura, *Linn.*			
H R	Hydrobia (Rissoa) ulvæ, *Penn.*			
H R	Lacuna crassior, *Mont.*			
H R	„ vincta, *Mont.*			

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H R	Littorina littorea, *Linn.* - -	D	E
H	„ rudis, *Maton* - -	D	E
H R	Natica Alderi, *Forbes* (= N. nitida).		
H	„ catena, *Da Costa.*		
H R	„ islandica, *Gmel.* (= N. helicoides).		
H R	Pleurotoma pyramidalis, *Ström.*		
H	„ rufa, *Mont.*		
H R	„ turricula, *Mont.*		
H R	Purpura lapillus, *Linn.* (including var. imbricata) - - . -	D	
H R	Scalaria communis, *Lam.*		
H R	Trochus cinerarius, *Linn.*		
H R	Trophon bamffius, *Mont.* (= T. truncatus).		
H	Trophon clathratus, *Linn.* (= T. scalariformis) - - -	D	
H R	Turritella terebra, *Sow.* (= T. communis) - - - -	D	E
R	Valvata piscinalis, *Müll.* (entered also as Trochus helicinus by Wood).		
R	Velutina undata, *J. Smith* (= V zonata).		

Artemis lincta and *Nassa nitida* were included by mistake in the list in the Fenland Memoir as on MR. HARMER'S authority. He has not found these species. *Astarte crebricostata*, also given, on the authority of PROF. SEELEY, was a wrong determination (? close-ribbed variety of *A. sulcata*).

In the Fenland Memoir (p. 203) MR. SKERTCHLY records *Equus fossilis* and *Elephas primigenius* as having been found at Chatteris.

MISCELLANEOUS.

There are here and there deposits as to the age and origin of which it is hard to speak, some indeed being little more than mere soils. In many cases such deposits are marked on the map by engraved words.

MR. HAWKINS notes that "over a great part of the tract known as Beechamwell Warren, westward of Swaffham, there is a sandy soil, as also over part of the neighbouring Swaffham Heath. This extends northward over parts of Narborough Field and of Narford Field. On the eastern side of the Obelisk, half a mile south of Narford Hall, there is a patch of sand that has been dug to the depth of 3 feet."

"A good deal of the high ground between High House and Castle Acre Wicken has a covering of sandy loam."

MR. WOODWARD records that "west of the Hall Farm, Rougham, a loamy earth, up to 3 feet thick, above the Boulder Clay, has been worked for brick-making."

S. and S.S.E. of Lakenheath Railway Station are some low sand-hills, which however have not been separated from the Alluvium on the map. This sand may be allied to that which occurs over a large area in the district to the south in a like position, quite hiding the Chalk westward of Eriswell.*

PALÆOLITHIC STONE IMPLEMENTS.

MR. SKERTCHLY'S notes on the occurrence of flint implements in the loam near Brandon, which underlies the Boulder Clay, have been given in an earlier chapter treating of those beds, and so also have the notes of occurrence in the gravels generally.

* The Geology of Parts of Cambridgeshire and Suffolk, p. 88. (1891.)

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The greater number of implements found in the district come however from gravels which geologists in general regard as newer than the Boulder Clay, and it will be convenient to group together notices of these, with the set of illustrations so kindly given by Sir J. Evans, whose description thereof will now be quoted,* the gravels in which they were found having been already described (pp. 72, 93–97).

The original of Fig. 25 is thus described:—"A very elegant pointed specimen, in my own collection. . . It is chipped with great skill, and brought to a fine point, the butt-end being comparatively blunt, so that it may have been used in the hand without being in any way hafted. At the shoulder, shown in the side view, a part of the original crust of the flint is left, and small portions are also left on the other face. . . Like many of the implements from the gravel, it is cracked in various directions, apparently from inward expansion, and would break up into fragments with a slight blow. A very sharp point, such as that presented by this implement, is not uncommonly met with in those found at Santon Downham."

Of Fig. 26 it is said:—"The original is also in my own collection, and is cracked in a similar manner. It is uniformly stained of a light buff colour, as are many of the implements from this spot, and has dendritic markings upon it, and in places, particles of ferruginous sand adhering to the surface. It is fairly symmetrical in contour, with an edge all round, which is somewhat blunted at what is the base in the figure. This edge, however, is not in one plane, but considerably curved, so that when seen sideways it forms an ogee curve, even more distinctly than appears from the figure. . . but whether this curvature was intentional it is impossible to say."

Fig. 27 "represents an implement of porcellanous, slightly ochreous flint . . in the collection of Mr. Robert Fitch . . of Norwich. Implements of this broad, ovate-lanceolate form are extremely uncommon, and this is a remarkably symmetrical specimen, of good workmanship, and almost equally convex on the two faces. A few implements, almost circular in outline, but of the same general character, have also been found at this spot."

Of Fig. 28 Sir John says: "The original . . is also in the collection of Mr. R. Fitch . . and presents an example of another rare form, almost crescent-like in character. There is frequently a slight want of symmetry between the two sides of the ordinary ovate implements, which gives them a tendency to assume this form, but I have never seen it so fully developed as in some of the implements from this place."

Of the locality of the above four implements Sir J. Evans adds these remarks: "Viewed as a whole, the implements from Santon Downham present a higher degree of finish, and a greater skill in chipping the required forms out of flint, than those found in the gravels of any other part of the valley of the Little Ouse, or, it may perhaps be added, of England or France."

Fig. 29 "presents a much narrower form than is usual among the River-Drift implements, and in outline closely approximates to some of the Neolithic rough-hewn celts. It is, however, much more convex on one face than on the other, and presents what are apparently signs of wear along both the sides and the ends, the broader of which is somewhat gouge-like in character."

Of Fig. 30, Sir John says that it is from a specimen in his own collection, which shows part of the original crust of the flint at the base. "It is a specimen of a thin broad type occasionally met with. Towards the point the edge bears all the appearance of having been worn away by use as a scraping tool."

The original of Fig. 31 "though so identical in form with many of the implements of flint, is formed of felstone, no doubt derived either from the Boulder Clay or from some other of the Glacial Beds. One face appears to show a considerable portion of the original surface of the block of stone from which the instrument was fashioned, but the whole surface is now somewhat

* The Ancient Stone Implements . . of Great Britain, pp. 501–507, 510, 511, 514, 515. (1872.)

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decomposed, so much so, that it is difficult to determine with certainty the nature of the material, which by some has been regarded as diorite . . One face has been skilfully clipped, the flakes having been removed in much the same manner as if the substance wrought had been flint. At one part of the other face there is a considerable shoulder between the central ridge and the edge near the butt, where, owing to the "grain" of the stone, the flakes have run in, and not come off kindly. The angles and edges are slightly rounded."

Of Fig. 32 SIR J. EVANS says that the original "was found by myself in the gravel near Brick-kiln Farm . . It is a broad flake, having a well-marked cone of percussion on the flat face. The other face shows, over nearly its own extent, the original surface of the quartzite pebble from which it has been formed. It has, however, had a portion removed on one side of the cone, apparently to produce a symmetrical form; and the whole of the edge at the broad end of the flake has been trimmed by chipping from the flat face, so as to produce a bevelled edge, which is now somewhat rounded, either by wear in the gravel or by use."

MR. H. PRIGG has classified the implements of the south-eastern part of our district and of that just to the south (Sheet 51, N.E.) as follows:—1. Flakes: 2. Rude Implements, almost unclassifiable: 3. Implements with a cutting edge all round (discoidal, oval, ovate, almond-shaped, and ovato-acuminate): 4. Pointed Implements (spear-shaped, wedge-shaped, and shoe-shaped).

He estimated that the number of implements "found during the last twenty years, within the watershed of the Lark [to the south] and Little Ouse alone [partly to the south], . . at 6000 . . exclusive of the simple form of the flake; indicating a population of some extent, over a considerable series of years, during which the art of working the flint progressed, and the forms of the implements were improved upon."*

MR. A. G. WRIGHT has kindly sent me a most interesting note of "an almond-shaped implement from March, of lustrous brown flint, weathered slightly in places, found about 20 feet below the surface in a part of the town called New Park, in digging foundations for buildings, about 1877." A full-sized photograph of this, from that gentleman, shows a good Palæolithic implement about 7¼ inches long by 3¾ broad. This single find of course, though as far as I know, the only one from the March gravel, disposes of the statement in the Fenland Memoir (p. 203) that "no flint implements have been found in the true marine fen gravels," and of conclusions based on such negative evidence, though MR. SKERTCHLY was justified in drawing them at the time that he did.

It has been noted, in the Fenland Memoir, that MR. MARSHALL FISHER, of Ely, has an implement said to be from the gravel of Downham, northward of Ely, and MR. W. MARSHALL, also of Ely, has another. The site is either at the southern border of our district, or just beyond it.

* *Proc. Norwich Geol. Soc.*, part vi. pp. 163, 165. (1882.)

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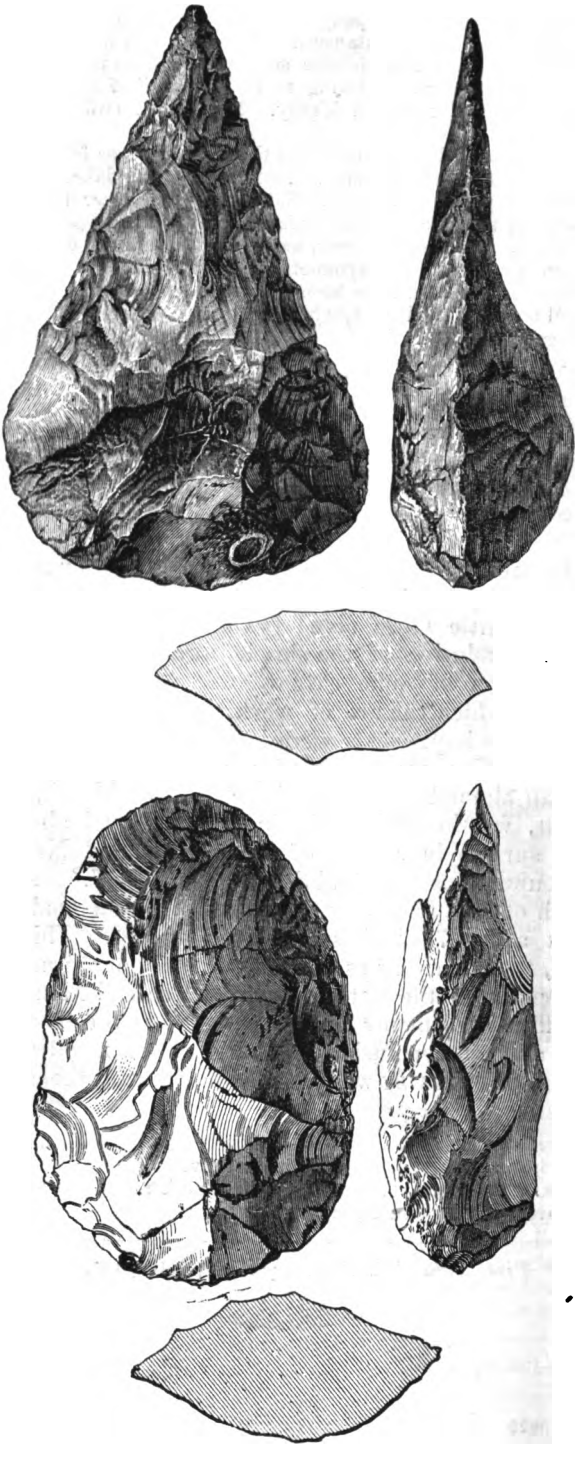
FIGS. 25, 26. *Flint Implements from Santon Downham.*



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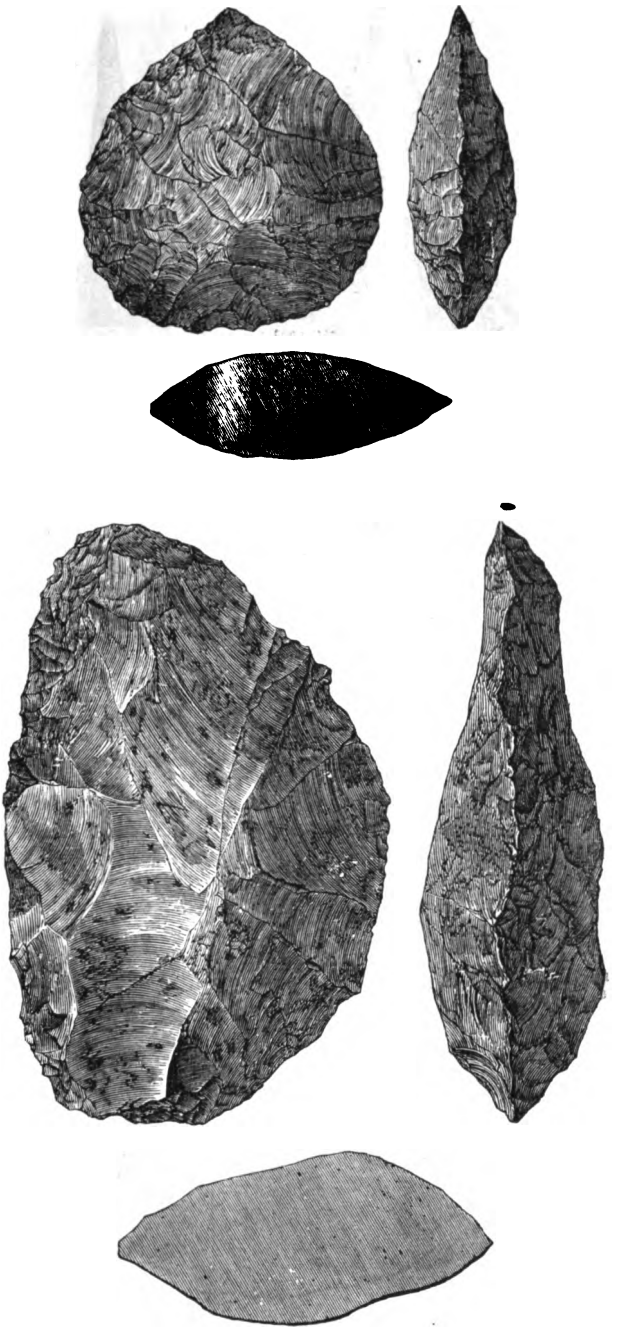
FIGS. 27, 28. *Flint Implements from Santon Downham.*



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FIGS. 29. *Flint Implement from Broomhill, near Brandon.*

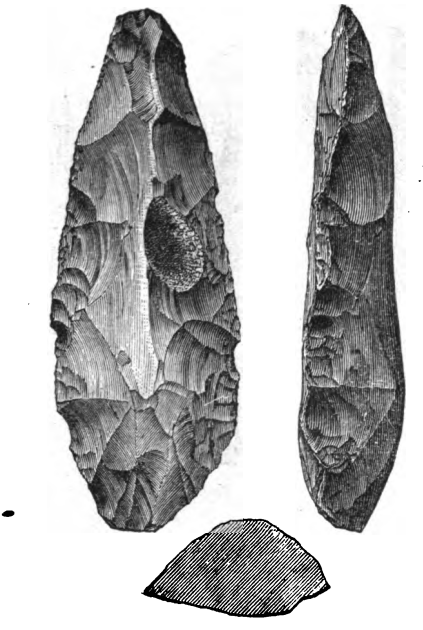
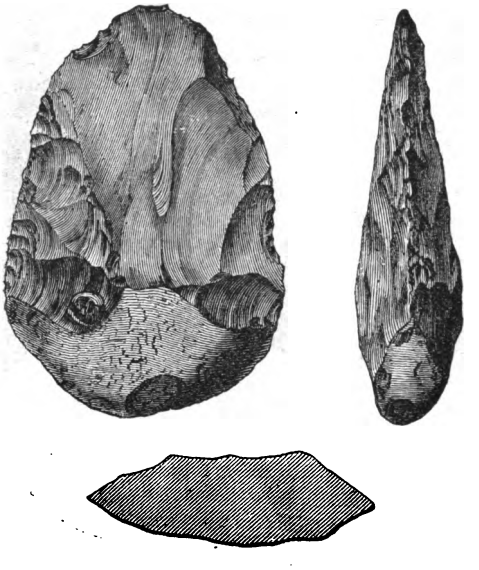


FIG. 30. *Flint Implement from Shrub Hill, Feltwell.*



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FIGS. 31. *Felstone Implement from Gravel Hill, Brandon.*

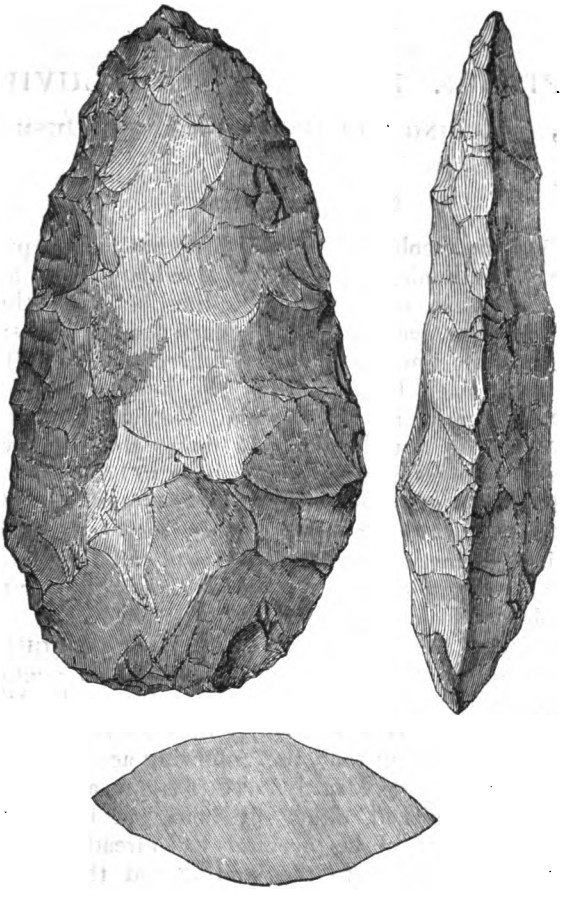
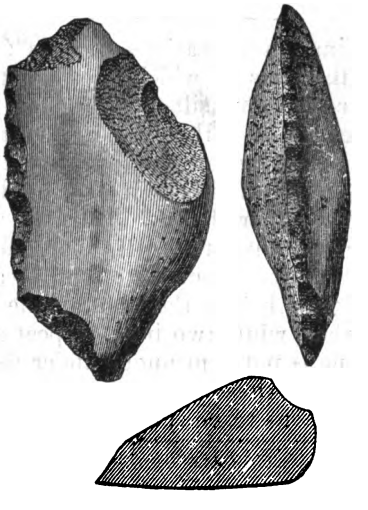


FIG. 32. *Quartzite Flake from Gravel Hill, Brandon.*



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CHAPTER 13. RECENT BEDS. ALLUVIUM.

The Fens, including the Marshes of the Ouse and of the Nene.

General Remarks.

Sheet 65 of the Geological Survey Map not only represents a greater area of the Fenland and of the Marshland than any other sheet, but also much of the dividing-line between those two divisions of the Fens, based on the occurrence at the surface of peat, etc., or of the Fen Silt. It may therefore be well here to reproduce under each head some of the more general of Mr. Skertchly's remarks in the Fenland Memoir, as well as those specially referring to our district. In doing this however some alterations and changes of arrangement have to be made.

He divided the whole tract into the *Gravel-land*, the *Peat-land*, and the *Silt-land;* but we have already disposed of the first, which is fairly distinct from the other two, and have now to do only with those two, which are formed of deposits newer than any of the gravels, and belong to the Recent Period.

The useful term Fen Silt was given by Mr. Skertchly to the more or less loamy beds of marine origin which occur over a broad tract on the western and southern sides of the Wash, the gradual silting up of part of which bay they prove.

It should be understood that the following account of the Fen beds is almost wholly by Mr. Skertchly, any additions to his work being distinguished, either by being in brackets [ ], or otherwise. Some part of his account has already been used in the Memoir on the district to the south,* and this need be only incidentally referred to here; but some more or less general remarks not used therein are now absorbed.

From the examination of various borings (some outside our district) a few of the facts to which they point may be noticed. The first is that the peat and silt do not form regular beds, but present every variation, and that the gravel alone is persistent. Secondly; while at some spots peat represents the whole fen series down to the gravel, in others it is subordinated to the silts and gravels, or is altogether absent. Thirdly; the peat is often so intimately connected with the silts, that the beds have been recorded as peat and clay. Fourthly; that occasionally the peat has commenced to grow before the end of the deposition of the gravel. Fifthly; that, while two beds of peat are shown in some places, the lower one is not continuous under the whole area.

The deductions from these facts are obvious; and, as I had arrived at the conclusions to be stated before the sections alluded

* The Geology of Parts of Cambridgeshire and Suffolk (51, N.), pp. 90–102, 106, 107. (1891.)

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to came into my possession, these afforded a pleasant confirmation of my views. Let us call the time during which the fen beds were being formed the Fen Period, then the deductions are as follows :—

1. Throughout the whole fen period the climate was favourable to the growth of peat, which formed whenever the sea had no access to a given area. Sometimes the alternations between marine and freshwater conditions were very rapid.
2. That the alternations between marine and freshwater conditions were very variable in the same and in different areas, and that no classification such as Upper Peat, Buttery Clay, Lower Peat, &c. can hold good.
3. That even where the sea has not interfered with the growth of peat that substance has not gone on forming continuously, but that intervals of dryness, of at least 150 years, occurred in which trees grew upon the surface of the peat.

The Peat.

(From the Fenland Memoir, pp. 4, 5, 128–132, 139–146, 151–154, 156, 160–166.)

Under this heading will be described not merely the great deposit which forms so large a portion of the surface of the Fenland, but several subterranean beds only shown in pits or by well-sections. These lower beds are irregular in extent and are not, as was formerly imagined, mere extensions of an Upper Peat beneath the silt, or a single bed to which the term Lower Peat could be applied.

Analysing various sections seen, three distinct levels of subterranean peat are shown to exist; but if these represent three distinct beds of peat they are mere wrecks, for they are much broken up. The complete elucidation of these subterranean beds must be left to local geologists, who alone can determine whether they are outliers of once wide-spread deposits, or merely isolated patches. I incline to the latter belief, there being so many undoubted cases of the rapid alternation of beds in short distances.

Southward of the boundary-line (the course of which is engraved on the map and referred to on pp. 126, 127) the whole Fen area is covered with peat. The peat-land therefore occupies nearly the entire west of the Fenland, and the whole of its southern area. There are in addition small outlying patches, in the silt-land, as north-west of Wisbech.

The precise extent of the peat-area cannot be determined in consequence of the boundaries being very obscure, for the peat thins out insensibly along its borders, and because the practice of claying the land, and the effects of cultivation and drainage have rendered boundaries more indistinct, which even originally faded away rather than formed definite lines.

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In mapping the peat it was found necessary to adopt more or less empirical data for the determination of boundaries. On the Norfolk and Suffolk side the problem is complicated by the uneven surface of the sand and gravel. In the little hollows peat has grown; atmospheric agents have worked down many of the small elevations of loose sand and spread the material over the peat, which in consequence appears to be interstratified with sand. Furthermore the true moss-peat has so intermingled with the moory turf, now forming in the sodden hollows, that it is impossible to discriminate between the ancient peat and its modern type. In this case an arbitrary line has been drawn showing the boundary of the true peat-land.

Yet another case may be cited, the boundary between the peat and the silt. We have above described how the peat dies away along its margins, but at its junction with the marine beds a fresh complication arises. It must be remembered that the Fenland has been, and is still, the battle ground of salt and fresh water. Sometimes the sea has pushed into the country of freshwater for a time, sometimes the rivers have invaded the district of the sea. The marks which the sea put upon the land were, in the latter period of the conflict, beds of light flocculent silt, which fell in a thin, pink and silvery sheet at high-water slack of each tide.

The cognisance of the freshwater was peat. Wherever freshwater stagnated, peat grew. And, as the sea was continually damming itself back, by piling up its silt-beds, the peat followed its retreating footsteps until the changing climate had so altered as to have become unfavourable to the growth of peat. Many times the sea burst its self-erected barriers and swept their *débris* back into the peat-country, and hence we find along the margin occasional banks of silt overlying the peat. This is no imaginary record. If the peat were still growing the same thing would take place now, and such hillocks were left when the sea broke into Marshland in 1862.

But the peat had to compete with a more formidable foe than the sea: the climate was growing drier. The waste soon became more rapid than the growth, and eventually peat ceased to grow at all, save in a very few favoured, sheltered nooks.

As the peat advanced towards the sea, it did so with continually diminishing vigour, and finally died upon the march. Hence one of the reasons for the obscure nature of the boundary. It was beaten in the struggle against climate, and the thin edges, like fallen outposts, attest how hardly it succumbed.

Throughout the peat-area, then, the boundaries are not rigidly correct, but are only approximately true, and even if six-inch maps were used, the exactitude could not be much enhanced, since the actual aspect is, as it were, blurred, like a drawing upon blotting paper.

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The physical features of the peat-land present a marked contrast to those of the gravel and silt-lands, and at once stamp it with individuality.

In the first place, although it occupies nearly half the Fenland, *no village occurs upon it*, with the exception of Benwick (N.W. of Chatteris), where the peat is thin, and the underlying gravel serves as a support for the buildings. The reason for this is that no solid foundation is afforded by the spongy peat. But few houses stand upon it, and these are supported upon piles driven deep into the clay beneath. Mr. Wells, of Holme, told me that the piles were very perishable, and that he was going to try concrete foundations near Whittlesey Mere, which would have to be laid 18 feet below the surface.

The perfect flatness of the landscape and the absence of scattered trees are among the most striking peculiarities. Trees are not wanting in many places, but they are almost exclusively lines of aspens and of willows, along the banks of the great drains. The absence of hedge-rows gives to the scene a strange openness, which imparts a singular sense of dreariness and of coldness. The even surface is a consequence of the mode of formation of the peat. The absence of hedge-rows results from the comparatively modern date of enclosure.

The long roads, again, possess distinct peculiarities in their blackness and straightness. I allude to the bye-roads and not to the highways or *rampars*, for these latter are raised above the general surface, are gravelled, and rank amongst the finest in the kingdom. The bye-ways, on the other hand, are merely broad, straight pieces of uncultivated land. In summer they are passable, for the dry peat crumbles into dust and renders the surface tolerably smooth, but when the rains of winter fall vehicles sink to the axles in the spongy mass, and the roads become practically useless. I have seen six horses try in vain to drag a loaded tumbril across a road; and have known a riding-horse to be bogged and to have to be shot, to save it from death by cold and starvation. These roads, commonly called *droves*, are peculiar to the peat-land, and they follow the courses of the dykes or drains, by which the land is kept in a fit state for culture. These peat-lands might almost be mapped by enclosing the areas on which the roads are long and quite straight.

The difference of aspect may, however, be felt more strikingly upon the plain than above it, for the transition from peat to silt is usually more or less abrupt. One of the best localities for observing this change is at Upwell, not because the difference is there more apparent, but because it bursts upon us more unexpectedly than at most other places. Going down the lane on the northern side of Beaupré Hall, the undulating silt, well studded with trees, lies on either hand. Suddenly an open, treeless landscape opens before one, creating a sensation akin to that experienced on unexpectedly coming upon the coast one thought was miles away. These features are mentioned, because, although they are

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not strictly geological phenomena, they are nevertheless dependent upon the geological structure of the district, and are of great value to the field-geologist. These things however are not to be realised at once, but only become apparent after some little experience in the wonderful atmospheric effects of fen-landscapes: then they are vivid enough.

The blackness of the soil is, of course, one of the best criteria of peat-land. But even this cannot be implicitly relied upon, for where the peat is very thin it is often difficult to judge between the traces of peat and the dark brown of a vegetable soil. Moreover, the colour is often a deep ruddy brown, and then the embarrassment is doubly increased, for the clays and silts assume just this colour when worked up into soil. Again, it is impossible to judge of colour towards sunset, especially when, as more often happens here than in most places, the whole landscape is tinged with golden beams. In the fens it is not unusual for sundown to infuse its radiance *into* the atmosphere, and not merely gild the sky. At such times geological mapping is impossible. The above remarks apply solely to places in which the peat is thin, but as it is precisely through such spots that the geological boundaries run, it is necessary to point out a source of error to the field-worker which, though it may seem a slight thing to others, is regarded by me as a very important fact; and I believe everyone who maps in the fens will arrive at a similar conclusion.

When the peat is over a foot thick there is not the slightest difficulty in determining its presence. The land is coaly black; and, even when crops cover it, the drains, which everywhere intersect it, reveal the presence of peat; and when in autumn these are choked with sedge, rush, reed, and *Jacobea*, the water-rats always turn out sufficient material to satisfy their biped brethren.

A strange and unmistakeable odour arises from the peat both in summer and winter.

In winter the land is sodden with rain, the dykes are full, and the country becomes almost impassable. In summer all is dry and parched, the minor drains are empty, and the dwellers in the fens are often reduced to straits for want of drinking-water. In the early summer mirages are not uncommon, and I have only observed them on the peat-land.

Nearly all the land is arable, but a few grass fields occur; overdraining, however, is rapidly destroying the pastures. [Mr. Cameron says that the peat-land south-westward of Stoke Ferry is not arable.]

Such is the general aspect of the peat-land, a division of the Fenland possessing more peculiarities than any other, and here covering a greater area than any similar deposit in Great Britain. So rare are stones over this land that an occasional pebble or brickbat is a godsend to thrushes and blackbirds, and the broken snail-shells lying in profusion around show how alive the birds are to the value of the curiosity.

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The upper part of the peat is in all cases much weathered and appears as a black or deep brown material, showing no trace of vegetable structure, and rapidly crumbling into cuboidal fragments. Where the underlying clay is within a few feet of the surface it is dug and spread over the peat soil, for the purpose of affording solidity, and the soil is greatly improved by the process. This claying of the land is one of the causes of the rapid disappearance of the peat. So rapidly does cultivation, combined with claying, destroy the peat, that over large areas the former presence of that deposit is only attested by the moory character of the soil.

Another important cause of this wasting away is the abstraction of water by the excessive drainage now in vogue. The land is rapidly settling down, and the peat, deprived of its moisture, shrinks into a much smaller bulk than it previously occupied. The peat beds are like so many huge sponges which, when relieved of the water they contain, shrink into much smaller bulk.

Mr. W. Marshall of Ely told me that the Hilgay Fen drainage-mill wheel originally dipped 6 feet, when the land was *bright*, that is just glistened with water, and that 26 years later it only dipped 20 inches under similar circumstances, showing a compression of 52 inches in that time, or an average of 2 inches a year.

In Wood Fen, between Ely and Littleport, 20 years ago [1854], the drains were maintained with 5 feet of water in them: their bottoms were peat and few trees, and no clay was found. In 1874 the peat was completely dug through to keep the dykes at the same depth, the trees formed a serious obstruction to the dykers, and only 2 feet 11 inches of water could be maintained. This gives a compression of 37 inches in 20 years, or an average of 1·35 inches a year.

[In the Fenland Memoir some of the figures in the last two paragraphs have been calculated wrongly: they are now corrected.]

Buried trees, the remains of a great forest, have long been known to occur in the fens, and their position was described as being at the base of the so-called Upper Peat; but no one seems to have suspected the existence of more than one forest, though at least five forests occur.

The roots are often to be seen in place, and the beds penetrated by rootlets are boulder clay, fen-clay, and occasionally gravel. A yew obtained by Mr. Marshall, of Ely, from Hilgay, penetrated into the sand, and then spread its roots out almost horizontally so as to keep within the sand, which is thin at that spot.

The following is a table of the places where evidence of buried forests has been got in or on the border of our district, where the trees lie deep and are reached only in isolated sections:

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where the forests are close to the surface, the trees often lie so thickly together that it would be difficult to select a spot from which they are absent, and so but one case is noted :—

Place.	Trees.	Depth, in Feet.	Thickness of Fen Beds, in Feet.	Nature of Base.	Observer.
Warboys Fen -	? - - -	12	18	Peat - -	Boring.
Wood Fen - -	Oak, Fir, Yew, Sallow, Alder.	1, 2, 3, 6, 10	10	- - -	S. B. J. S.
Manea - -	Oak, Yew - -	25	?	? - -	S. B. J. S.
Hilgay - -	„ „ - -	10	10	Clay or Sand	W. Marshall.
Welsoken - -	Sallow - -	6	12+	Clay - -	S. B. J. S.
Baubrink Cut -	Alder, Hazel - -	20	20+	„ - -	C. B. Rose.
Lynn - - -	„ „ - -	13	43	„ - -	S. Smith.

The earliest records combine to prove that the Fen border-lands, especially in the counties of Huntingdon, Cambridge, and Lincoln, were covered with forests, and there can be no reasonable doubt that such was their condition long before the dawn of that civilisation which everywhere distinguishes itself by a mania for cutting down trees. So long however as the waters, salt or fresh, held dominion over the lowlands the forests stopped upon the borders; and the saplings, which spread so industriously, and the seeds which are strewn so widely met with no encouragement until the land became firm. Then indeed they grew and throve, creeping down into the fens as the waters retreated, and thus accounting for the fact that the true forest of timber trees is confined chiefly to the neighbourhood of the highlands, and only the moisture-loving willows, sallows, and alders decked the open country.

Throughout what may be called "the fen period," (from the gravel upwards), the climate was favourable to the production of peat. But there were intervals, even when the sea held no sway, in which it did not form, or at least only in limited areas. It was during these respites from aqueous dominion that the forests grew, and the longest of them was not very long before the end of the peat-growth, for we find at from four to eight feet over the Isle of Ely and Lincolnshire a wide-spread multitude of oaks, &c. They grew for the most part upon a thin layer of peat and sent their roots down into the fen-clay and when that is thin, as in Ring Moor, near Billinghay (in Sheet 70), into the older beds, in this case consisting of Boulder Clay.

In the neighbourhood of Hilgay the yews are abundant in the sand, but this bed is not continuous, and where the fen-base is formed of Kimeridge Clay the yew gives place to oak.

A very noticeable feature throughout the Fenland is the bending of the existing trees toward the north-east. Many of the dykes and droves are bordered by aspens, and when a long line of these slender trees is seen bowed in one direction the appearance is very striking. This north-easterly direction is toward the sea, but near the coast the sea-breezes exercise their influence, and the trees all grow with a bend away from the sea, as may be observed at Hunstanton.

This subject has an especial interest to the geologist in connection with the direction in which the trees of the buried forests beneath the peat are found to lie. Throughout the main expanse

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of peat, whenever the trees are seen in place, the direction in which they lie is almost invariably north-east and south-west, varying but a few degrees on either side. In other words, the buried trees lie in the same position as the living trees would, if free to fall.

The cause of the uniform direction of the trees is to be sought in the direction of the prevalent winds, and we can conclusively prove this by reference to the recorded observations on the winds of the fen-land. From these it appears that the S.W. wind prevails; the nearest rival is the N.W., but the S.W. wind has the advantage in the proportion of nearly 2 to 1; the N.E. wind is next in order, but the proportion is still more favourable to the "sou-wester." The chances are therefore greatly in favour of the trees falling in a N.E. and S.W. direction, and indeed the modern trees when uprooted take this course.

In speculating upon the causes of the destruction of the forests, the direction of the trees must be constantly borne in mind. But this is exactly what most of the writers on the subject have omitted to do, and hence the opinion has prevailed that the forests were cut down by the Romans in order to destroy the hiding places of the Britons. But this position is untenable, and the peat, which is itself for the most part more recent than the forest, is much older than the Roman period.

We must however remember that the casual uprooting of a tree in a gale, and the gradual decay of old forest-monarchs will not account for the presence of the great numbers of trees which form the buried forest. The trees must have died *en masse*, and remained for years standing as the shadeless skeleton of a once dense forest before they succumbed to the influence of the wind. The agency of man was not the cause of this universal death, for the trees are mostly *broken* off and never cut. A pseudo-level appearance is often presented by the broken stumps, in consequence of the peat having filled up the irregularities of the fracture; and this, together with the uniform height of the stumps, undoubtedly gave rise to the opinion that the trees had been cut down.

Another supposition is that the forest was destroyed by fire, and old writers confidently assert that numbers of trees show signs of having been burned down. This again is a misconception, and seems to have arisen from the blackness of the oak wood, and still more from the carbonaceous appearance of the decayed bark, but it is certainly not true that to this agent we must ascribe the loss of the forest. Burned stumps are indeed to be found, notably in Wood Fen, between the highlands of Ely and Littleport. My attention was directed to this place by MR. W. MARSHALL, of Ely, who showed me specimens of undoubted charcoal got by himself. I carefully examined the locality, and on one occasion was accompanied by MR. MARSHALL FISHER, also of Ely. We found many burnt stumps in place and several slightly charred trunks, but MR. FISHER'S conclusion was that the burning was of recent date, and in this opinion I agree. The reason for rejecting the notion of ancient burning is as follows. It is the custom over the peat-district to dig holes and to set fire to the peat, which burns gradually across whole fields, and in autumn the entire surface of the ground may be seen burning, seldom with flame, often with little smoke, and so quietly that I have sometimes walked unwittingly into the smouldering ashes. The burning peat fills the atmosphere with a peculiar haze, locally known as fen-smoke, the presence of which is often annoyingly indicated, at Ely at any rate, by the impossibility of getting clear photo-heliographs for days together. The object of the process is to obtain at little cost the valuable manure afforded by the peat-ash, and the peat smoulders for weeks. Now the fire must often penetrate to the stumps and trunks of the buried trees and char their *upper* surfaces, especially in such localities as Wood Fen, where the trees are within a foot or two feet of the surface. Out of about 50 charred trees not one showed the slightest trace of fire, except upon the upper surface, even the trunks being quite untouched

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beneath. If the trees had been destroyed by fire they would be charred *all round*, and as this is never the case we may dismiss fire from the probable causes of the destruction of the forest.

Another, and much more probable, cause is the chilling effect of the growth of peat, to which indeed I am inclined to ascribe the destruction of the forest. That the peat itself, and not the stagnant water, proved so deadly is probable; for in the great Matto of the Amazons, and in other localities, trees thrive though several feet of water cover the ground for months at a time. It is difficult not to ascribe some influence to the peat, because the trees have often broken across at a height corresponding with the thickness of that deposit. If we imagine a tolerably well-drained forest-land converted gradually into a shallow pool, in consequence of the rivers being no longer capable of discharging the flood-waters; and the fast growing *Hypnum* and other mosses, with bog-plants of many species, taking the place of the green sward, whose decay instead of producing wood-soil, forms dank peat, which clings around the trunks of the trees and arrests the ascent of the sap, by cooling the trunks to the heart-wood, we can understand how the forest's vigour is checked, and its enfeebled life at length utterly destroyed. For a time the leafless oaks would maintain their ground, but the fell influence of the sodden peat, eating into the stems which had no power to resist, would undermine their strength and they would yield to the unceasing pressure of the wind, and falling, be entombed in the material which, their destroyer in life, became their preserver in death.

Peat itself is not an unkindly soil for the growth of trees, as is observable both here and in some of the Irish and Danish bogs, where definite horizons of trees are seen, showing that when the waters abated and the bog became tolerably firm ground the land again supported trees in abundance.

It is interesting to observe that much as the physical features have changed, and the meteorological condition too, the fickle wind which bloweth where it listeth has been constant, and as steadily blew from the south-west over the old forest as it does now over willows, aspens, and anemometers.

In going eastward from Thorney (in Sheet 64), along its boundary [marked by a dotted line on the map], the peat will be seen to die away upon the surface of the marine silts and clays. As we approach Boarden House Bridge thin patches of silt encroach upon the dark peat-soil, and at the eighth milestone a creek of silt [not shown on the map] runs across the road at the *same level as the peat surface* (six feet above Ordnance Datum). Thence to the bridge at Guyhirn the peat occupies the surface, and is seen three feet in thickness in the ditches close to the bridge. The land here rises about four feet, and the elevation is formed by the imposition of marine beds upon the peat.

The boundary of the peat then runs east to Cherry Tree Hill a slight elevation of about seven feet, formed by the marine beds (indeed anything up which water will not run is called a *hill* in the fens). It then curves southward, passing by March, and then eastward by the north of Stonea to Welney, runs southward again to Littleport. [From Littleport the boundary runs northward, along the other side of the Old Croft or Old Welney River, to about a mile east of Outwell.]

The triangular space between Cherry Tree Hill, Welney and Outwell is occupied by marine beds, and, running into the heart of the peat-country, maps out the tidal depositions of the ancient Ouse River, whose decayed channel may be traced in the ditch called the Croft River, which still partly separates the counties

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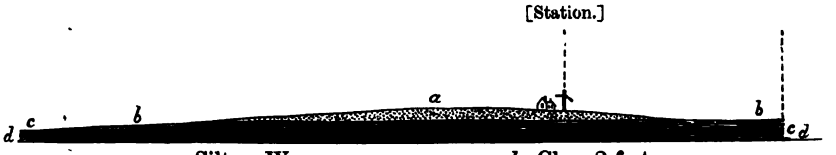
of Cambridge and Norfolk. The whole of this marine area lies a few feet higher than the adjacent peat-land; and the peat, tolerably continuous beneath it, extends northward to the coast and westward as far as Gedney Hill, never more than 8 feet from the surface and generally within 4 feet. [The boundary runs north-eastward from Outwell to east of Middle Drove Railway Station, and then soon turns south-eastward to the Ouse near Downham Market.]

The peat is continued northward of its boundary-line, beneath the thin covering of silt which hides it in the neighbourhood of Wisbech and Lynn.

Starting from the windmill by Cherry Tree Hill Farm, and walking eastward along the road to Pear Tree Hill Station, we pass in succession the edges of the peat, a marine clay, and fine sandy warp or silt. Beneath the peat another bed of marine clay is seen (see Fig. 33). A little east of the station the clay bed *b* crops out again. [There seems to be some error here, the windmill on the map being nearer to Pear Tree Hill Farm than to Cherry Tree Hill Farm.]

FIG. 33. *Section across Pear Tree Hill.*

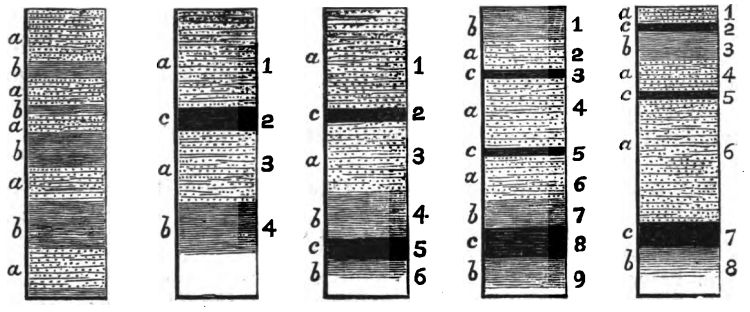


a. Silt or Warp. *b*. Clay, 2 feet.
c. Peat, a foot. *d*. Clay, 2 feet.
Vertical scale vastly exaggerated.

Proceeding still eastward we find the peat at intervals beneath the marine beds, and at Three Holes Bridge, on Pophams Eau, at Upwell, we come upon a fine series of sections which extend, at intervals of about 50 yards, as far as Nordelph, a distance of three miles.

These sections will be described somewhat in detail, since they occur in a peculiar district, in which the marine and freshwater beds have alternated in rapid succession. It must be remembered that the marine beds above the peat are the deposits of the old Ouse, which formerly debouched into the Wash at Wisbech. In Fig. 34 five sections are given reaching from the top of the bank to a foot or so below the water-level. No. 1, is at the junction of Popham's Eau with the Middle Level Drain; No. 2, is 100 yards further east No. 3, 50 yards east of No. 2; No. 4, 60 yards east of No. 3; No. 5, 50 yards east of No. 4.

Fig. 34. *Sections along Popham's Eau.*



a. Warp. *b*. Clay. *c*. Peat.

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No. 1.—In this section 15 feet of laminated sandy silt or warp, and marine clay are seen without any trace of peat. At this point, therefore, the peat-beds are cut away, or have never been deposited. The locality is half a mile east of the old river, here called the Old Welney River, and probably in the bed of the ancient river itself; for in estimating the size of the old stream we must not judge by the present configuration of the surface, but draw our inferences from the geological data which point out the physical geography of the past. At the time when these beds were formed the mouth of the old river was probably south of Wisbech.

No. 2.—At this point the section is as follows, to the depth of 12 feet:—

1. Laminated Silt or warp, with many *Scrobicularia piperata*, some young - - - - - 5 feet.
2. Peat, black and carbonised - - - - 6 in. to 1 foot.
3. Laminated Silt or warp - - - - - - 4 feet.
4. Clay - - - - - - - - 2 „

The un-marked portion of the figure was obscured and it is probable the lowest bed of peat seen in the remaining sections occurs here also. It is to be particularly remarked that *the peat marks a break in the succession of marine deposits;* which break must have been of some years' duration to admit of the formation of the bed. Again the fine laminated silt above and below the peat is a tidal deposit and is only formed in shallow water, as we shall show in a future chapter. The clay at the base of the section may be deposited in deeper water. Hence this section shows us a gradual silting up of the channel, and, after the period of land-conditions, as gradual a warping up of the newer channel.

No. 3.—The section at this spot, nearly 15 feet deep, shows:—

	Ft.	In.
1. Laminated Silt or warp, with *Scrobicularia piperata* and *Cardium edule* - - - - - - -	5	0
2. Peat, mixed with Clay - - - - - -	0	4
3. Laminated silt or warp - - - - - -	4	0
4. Clay - - - - - - - -	3	0
5. Peat, pure and black - - - - - -	1	6
6. Clay - - - - - - seen to	1	0

This section is similar to the above and almost the same remarks apply to it. The upper peat is thinner, and being mixed with clay shows that a great struggle had to be maintained with the salt water. The lower peat is intercalated in a deposit of clay, which evinces more sudden change from salt to fresh water conditions than the case before described.

No. 4.—Here we have the following section, 14 feet deep:—

	Ft.
1. Clay, with *Scrobicularia piperata* and *Cardium edule* - - -	2
2. Silt or warp „ „ „ „ - - -	1
3. Peat, mixed with Clay - - - - - -	¼
4. Silt or warp, with *Scrobicularia piperata* and *Cardium edule* -	4
5. Peat, mixed with Clay - - - - - -	¼
6. Silt or warp, with *Scrobicularia piperata* and *Cardium edule* -	3
7. Clay „ „ „ „ - -	1
8. Peat, pure and black - - - - - - -	1½
9. Clay - - - - - - - seen to	1

We have now two thin beds of peat under the same conditions as in Section No. 3. The lower peat-bed still persists.

No. 5.—This spot affords the following section, also 14 feet deep:—

	Ft.
1. Silt or warp, with *Scrobicularia piperata* and *Cardium edule* -	¾
2. Peaty clay - - - - - traces to	¼
3. Clay, with *Scrobicularia piperata* and *Cardium edule* - -	2
4. Silt or warp „ „ „ „	2
5. Peaty clay - - - - - - -	½
6. Silt or warp, with *Scrobicularia piperata* and *Cardium edule* -	5
7. Peat, pure and black - - - - - -	1½
8. Clay - - - - - - - seen to	2

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It will be noticed that the uppermost thin beds of peat in 4 and 5 are not the same.

Before continuing our sections let us see how far we are now justified in considering the beds to have been formed near the mouth of an estuary, and bordering land close to the sea-level. The presence of *Scrobicularia piperata* and *Cardium edule* at once declares the marine character of the deposits, and the dwarfed nature of the cockle-shells proclaim the water to have been only brackish. In the thin peat-beds no wood occurs save a few drifted fragments, but in the lowest bed, which being thicker shows the land-conditions to have prevailed for some time, we find abundant roots, branches and pieces of stems of sallows and of willows; just such trees as would first grow upon the dank water-side. The lowest bed of clay is part of what may be called the original marine deposit of the Fenland, and is considerably older than the overlying beds.

Still further east we trace the thin bed of peat seen in Section No. 5, and the lowest bed, continuously as far as the avenue which abuts upon the Eau, 1 mile 7 chains east of Three Holes Bridge. The land is gradually sloping to the east, and at this point the section is as represented in Fig. 35, which is drawn to half the scale of the sections in Fig. 34. The thin bed of clayey peat is persistent, but the thick bed of peat ends abruptly with a feather-edge. Following up this drain we observe the peat to come on again, as shown in the section, Fig. 36.

The little creek intersected at C (Fig. 36) is interesting. On reference to Fig. 37, in which it is represented on a larger scale, it will be seen that the peat is denuded on either side of the trough, and the section filled up with clays and silt. But above the peat *d* a number of peat-seams, alternating with clay *c* occur. These clearly prove the alternating character of the country between marine and fresh-water conditions; and, moreover, that the climate was such as to favour the growth of peat. Indeed hundreds of sections throughout the Fenland render it certain that from the time when the gravel was deposited until comparatively recent times peat was formed wherever fresh-water stagnated. It is impossible to refer the growth of this material to any one period in the history of the Fens.

This series of sections proves that the silting up of the old Ouse estuary was an intermittent action, that the surface of the estuary was intersected by numerous creeks, and that peat immediately commenced to grow when the salt water left any portion of the surface for a time. On the shores of the Wash similar creeks abound, but no peat grows. A little salt water is not unfavourable to the growth of peat, for we often find small interbedded patches of marine silts full of cockle- and mussel-shells.

Speaking of the Fen between Hilgay and Methwold Mr. Cameron notes that "small waste patches of heather-covered peat still remain, in their original wild state."

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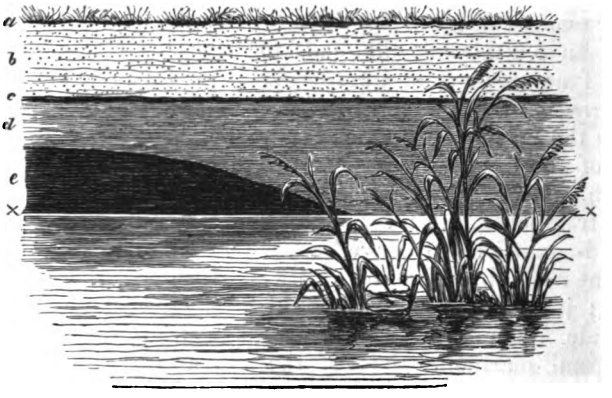
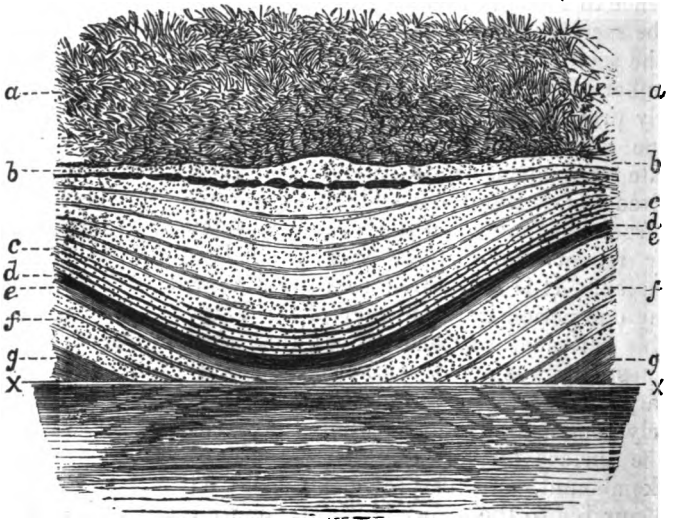
FIG. 35. *Section at the Avenue on Popham's Eau.*



a. Traces of peat.
b. Laminated silt.
c. Peat mixed with clay.
d. Clay, with the rib and humerus of a small mammal.
e. Peat.
× × Water-line.

FIG. 37. *Part of Section on Popham's Eau.* (*C. of Fig.* 36, *enlarged.*)



a. Overgrown bank.
b. Laminated silt.
c. Fine seams of peat.
d. Peat.
e. Clay.
f, g. Silt.
× × Water-level.

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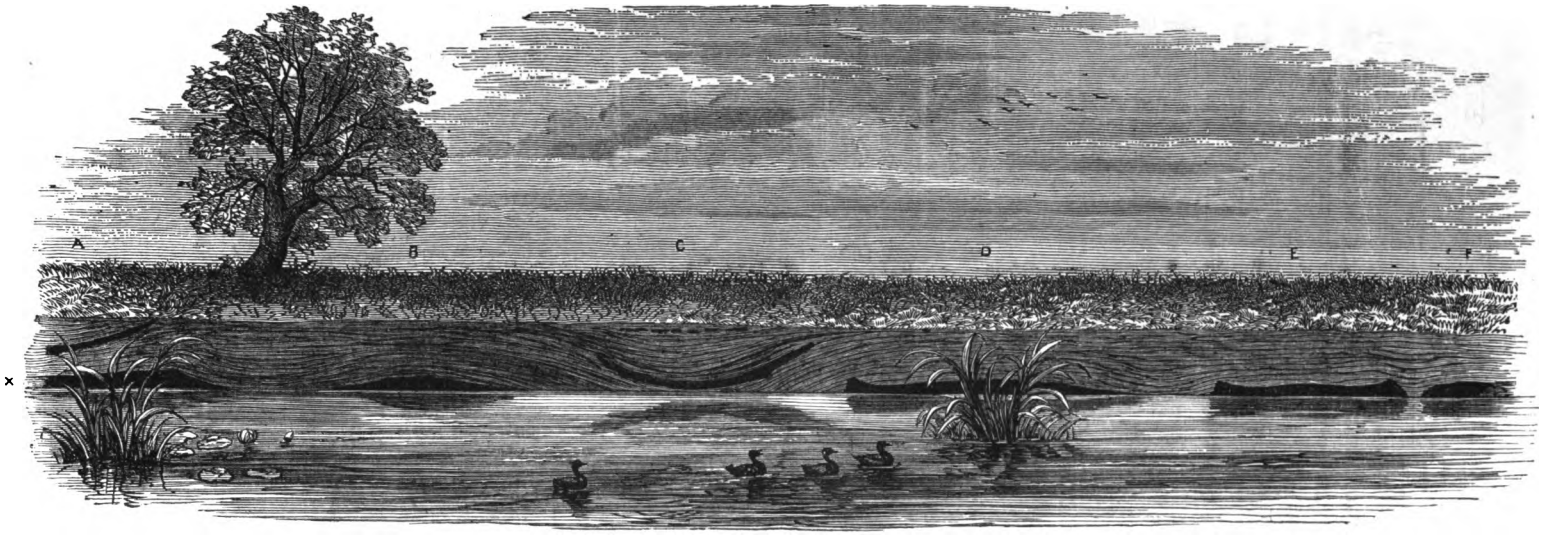
FIG. 36. *Section along Popham's Eau.*



× × Water-level.

Somewhat generalised, the patches of peat (black) being brought nearer together than is actually the case. The beds can be seen below the water, though not shown in the figure. A is near to Fig. 35. Between A and B the peat is discontinuous. At B a lenticular mass of peat occurs, the clay and silt arching over it. At C a small creek is intersected, of which Fig. 37 is an enlarged sketch. At D the peat is again continuous for 100 yards. At E the peat occurs with abruptly sloping ends, and overlaid (as in the trough at C) by clay, with many fine seams of peat. [No reference to F.]

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Shell Marl.

In 1850 Mr. W. J. Hamilton described "a peculiar bed of white, chalky-looking marl, partly overlying and partly interstratified with the black peaty soil through which the . . Railway has been cut between . . Littleport and Downham." This paper seems to have escaped notice in the Fenland Memoir. The author goes on to say: "The bed is seen soon after leaving Littleport, and may be traced continuously for many miles, varying considerably in thickness . . In some places it is seen on the surface, in others it approaches it so nearly as to be turned up with the plough, while in others again it is two or three feet below the surface."

"On washing out the marl I found a considerable number of land and freshwater shells, of existing species." [See list, p. 140.]

"Innumerable seed-vessels of *Chara* . . and numerous *Entomostraca*" also occurred.

After the reading of this paper the following further information was got: "The upper peat averages about twelve inches in thickness. The white marl runs about fifteen inches thick; but in some places it is nearly five feet thick. The black peat under the marl varies from three to seven feet in thickness; and under it is said to lie a blue soft clay. This formation extends about two miles on the west, and 1¼ mile on the east of the railway, and for about seven miles in length."*

* *Quart. Journ. Geol. Soc.*, vol. vi. pp. 451–453.

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CHAPTER 14. RECENT BEDS. ALLUVIUM.

The Fens, etc. (*continued*).

(Chiefly from the Fenland Memoir, pp. 4, 5, 173–177.)

The Fen Silt.

In treating of the peat many questions bearing upon the silt were discussed and such points will not be again noticed.

I have preferred simply to call this deposit Fen Silt as a comprehensive term embracing the different phases the deposit assumes. Similar deposits have elsewhere been termed "Scrobicularia clay," from the prevalence of *Scrobicularia piperata*. This term has not been adopted because such clay is only one aspect of the fen marine beds. Neither has the well-known fen term "buttery clay" been accepted for similar reasons. "Warp," again, is open to the same objections; whereas the term *silt* equally applies to the sandy and clayey facies, referring only to the mode of formation, and not to mineralogical or palæontological accidents.

It has been supposed that beneath the peat a bed of unctuous clay, locally known as "buttery clay," was universally found, and that the sandy warp was a perfectly distinct thing. But this clay, the Scrobicularia clay and the warp are only phases of one deposit, there is no distinct "buttery clay"; all the beds included as silt are of marine origin; and there have been many oscillations between land and marine conditions. This last case, however, has been pretty fully worked out in speaking of the peat.

The buttery clay acquired its spurious importance from the fen having been first studied in South Lincolnshire and in the neighbourhood of Cambridge, where indeed this clay is tolerably persistent, but when a wide area is examined it appears that this is only a local character. The name has been adopted as that of a determinable bed, but the proofs of local character are so abundant and indisputable that I hope my name "Fen Silt" will be allowed to supplant the others. It is true that buttery clay in its typical character can be easily discriminated, but it merges into Scrobicularia clay on the one hand, and into sandy warp on the other, as Prof. Bonney admits, though he does not recognize the existence of the great clay and warp deposits to the east.* Indeed the Scrobicularia clay often only differs from the buttery clay in the presence of the bivalve from which it derives its name.

The Fen Silt can be most readily described under two facies: clay and warp.

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* Geology of Cambridgeshire, p. 58.

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The clay varies in colour from light to dark blue and purple, but is often mottled blue and purple. It is generally tolerably free from sand and often contains carbonaceous markings, fragments of wood, and occasionally drifted trunks of sallow and willow.

When wood is plentiful the bright blue phosphate of iron (*Vivianite*) occurs in amorphous earthy lumps and streaks, varying in size from fine specks to bits as large as a bean. Stones are very rare in it, nor is this to be wondered at when we remember that the clay is a tidal deposit brought up by the sea, and not material washed down from the adjacent land. It is seldom bedded, but generally breaks up into rounded lumps with a glistening surface. Its unctuous character in some places has caused the name "sheep's ointment" to be given to it, a nasty dark blue substance which it much resembles; this, however, is only a local variety. When the roots of the reed (*Arundo phragmites*) have penetrated it, it becomes very fetid and is then termed "bear's muck," which poetical appellation is also applied to it when full of peaty matter, and the stems of the coarse grass still known to fen-men by the Saxon name "lead" (Saxon lid, *Poa aquatica*). It is to be noted that reed-roots penetrate very deep, and pierce hard materials in an astonishing manner. I have seen one which had bored right through an oak-trunk lying in the peat, and the roots may often be seen passing through sallow-trunks.

It is also frequently called "fen clay" to distinguish it from the "strong highland clay," Oxford or Kimeridge, as the case may be.

The organic remains consist almost solely of *Scrobicularia piperata*, many in single valves, but a fair average with both valves as when the animal lived. a few shells of *Tellina balthica* occur, and in places dwarfed specimens of *Cardium edule*, *Mytilus edulis*, and *Ostrea edulis*. Rarely, as at Quadring (Lincolnshire), little *Rissoæ* are plentiful. Here and there a few bones of *Bos*, *Sus*, whale, seal, and grampus are exhumed, but very sparingly. I have never seen a *Mya* or *Solen*, though they are common enough in the Wash, neither does the *Cyprina islandica* occur, though it also lives in the bay. Foraminifera are exceedingly plentiful throughout both clay and warp, and are found right up to the borders of the highland, which is not the case with the mollusca.

The warp is a very fine light-reddish-brown sandy deposit, in fine laminæ which sparkle in the sun, with fragments of mica and comminuted shell. It is not so widely spread as the clay, but forms most of the surface of the ground in the neighbourhood of the sea, fills up old creeks, forms little hillocks, and extends far inland in places. The warp gives to the surface of the ground a ruddy tint, very distinct from the coaly peat-surface, and it is not unusual to hear of "red fen" and "black fen." It is very full of Foraminifera, hardly a square inch being destitute of their remains.

That the different clays and warp are in reality but one deposit cannot be doubted by anyone who has watched the silt forming on the coast or in the rivers. Every variety can be observed in process of deposition. As a rule the clay is thrown down in deeper water than the warp, as may be observed along the timbered river-face at Wisbech. Now these two materials are forming every tide, and the clay is often the exact counterpart of the "buttery clay."

The silt-land occupies the northern and central parts of the Fenland, bordering upon the Wash, and is in extent half of the fen-district. The soil is clayey and silty and the surface of the land somewhat uneven, thereby affording a marked contrast to the level surface of the peat. The general elevation is somewhat higher than that of the peat-land, averaging about 15 feet above Ordnance Datum. Villages and towns are plentifully distributed upon it, as the silty beds afford good foundations. No water can be obtained

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by wells, except in small quantities, and of inferior quality. The supply is derived from the dykes and rivers, or in the case of large towns (such as Wisbech) is conveyed in pipes from the high land several miles distant. Hedge-rows are plentiful and the roads often remarkably crooked. Altogether this division is unmistakable in its physical aspect, though in some parts the silt-land lies as as low and is as level as the peat. For similar reasons to those before given these low-lying silt-lands were among the last to be enclosed and cultivated, and upon them we find the absence of hedge-rows, and the undeviating roads so characteristic of newly reclaimed fen.

In the summer of 1873 I investigated a curious case of the entombment of the ova of prawns in the marine silt for a lengthy period. MR. S. H. MILLER directed my attention to the case and accompanied me on my visit. The facts were communicated to "Land and Water," and specimens were got which lived for a long time in the Brighton Aquarium.

At Walsoken brickyard, near Wisbech, pits are sunk in the clay, and in the year 1859 a bed of fine sand or silt was pierced at a depth of 15 feet. From this bed a strong salt spring rose, the water of which was much more saline than that of the river in the neighbourhood, and this, mixing with the fresh water in other parts of the pit, rendered it so brackish as to kill the pike, though the carp, tench, and insects seemed unaffected by the change. Shortly after this incursion of salt water prawns began to appear in the pit, and the supposition is that their ova were embedded in the marine silt and kept alive by the salt water with which the bed was charged, and that the recurrence of favourable conditions of open water and light enabled them to hatch, and since that time they have abounded in the pits. The largest individuals are about 2½ inches in length, a size never attained in the river, nor, I believe, in the Wash itself.

The position of the pits is about three quarters of a mile from the Roman banks, on the land side, and a mile and a half from the river Nene, up which the same species comes with the tide.

There are many pits in this district in which the water rising from the silt is brackish, but I have never met with another case in which marine organisms were found living, though nearly every pit within an area of 1,000 square miles was examined. In some places a communication is kept up with the sea by beds of quick silt, and wells become distinctly brackish during high spring-tides. In the present instance such does not seem to be the case, and one is driven to the conclusion that the prawns must have been introduced accidentally, or that the ova were embedded in the silt itself.

It is highly improbable that the prawns were introduced wilfully for the mystification of naturalists, for the latter are rarer than prawns about here, and the time of the appearance of the prawns just after the spring was tapped, and the fact of them all being very small at first are in favour of a natural mode of introduction. Neither is it probable that the ova were introduced by sea-birds in one of their very rare visits to this pit, for the ova are carried by the females until they hatch, and could not become attached to the bird, neither could they have survived the process of digestion as some seeds do. Besides, considering the great number of open pits hereabouts which have been unused for years and so afford much better protection for sea-birds, the introduction of prawns ought to have been more general on such a supposition. True, most of the pits contain fresh, or only slightly brackish water, but prawns seem to live almost as well in fresh as in salt water, and I have frequently noticed them miles above locks on tidal streams, where the water is not even appreciably brackish. The prawns in question were kept for weeks in fresh water, and they were then killed by accident. Nevertheless, in no other pit have they been found, though they would hardly escape notice, since these spots afford valuable fishing-resorts.

The balance of evidence is decidedly in favour of the burial of the ova in the silt, which is so quick as to be dangerous to stand upon, and would afford plenty of water for their preservation. The only difficulty attaching to this supposition is the length of time during which the ova must have lain dormant.

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The Roman banks are about 1,700 years old, and at least 3,000 years must have elapsed since the area of the pits at the depth in question were covered with sea water. Yet I see no other explanation, and am strongly inclined to believe such to have been the case.

To the above account, by MR. SKERTCHLY, may be added some remarks on the Fen Silt of part of the eastern border of the Fens, from my own notes, of later date, made when carrying on the Survey of the neighbourhood of Lynn.

In and near that town, both to the north and to the south, and also near Watlington, the surface of the Marshland is not only uneven (as noticed generally by MR. SKERTCHLY), but the unevenness takes a moundy or hummocky form, tracts, sometimes very small, sometimes of fair size, rising slightly above the level of the surrounding land, giving rise to dry patches of loam, of much the same look as the low islands of River Gravel that occur in various alluvial tracts, but consisting of the same material as the surrounding marsh-land, and not of other beds rising up through the Alluvium.

I took the trouble to roughly map out some of these moundy masses, and in doing this, near Lynn, was led to the conclusion that the form might be owing to tidal action, the lower levels between the mounds being the creeks along which the water had flowed up and down at the time when that part of the country was open to the sea, in the same manner as often occurs now. The mounds themselves were probably but rarely submerged, only at very high tides, and were the district flooded they would form a refuge for cattle.

At Watlington some of the moundy alluvium, just southward of Magdalen Road Station, seems to be higher than the edge of the gravel between it and the village.

On the north of Lynn the line to the Docks, from the Eastern and Midlands Railway, cuts through two very small but well-marked mounds in the marsh, touching the northern side of the stream above the Waterworks. These are of the usual brown loam that here forms the Alluvium, and they seem to show traces of an old surface, by a thin black layer, chiefly in the western mound, and by patches of apparently burnt clay. (1883.)

Sections.

(Chiefly from the Fenland Memoir, pp. 266–270.)

Some of the sections in our district given in the Fenland Memoir have already been described above: some find their place in the Appendix of Borings: the rest follow here, with others. Unfortunately in that Memoir many sections have been printed in duplicate.

4 miles west of Chatteris.

Peat, with oaks and willow roots at the base, sticking into the bed below, 6 feet.
Clay, 1½ feet.
Reddish sand, dug to 3 feet.

Manea Fen.

Peat, 4 to 5 feet.
Clay (fossiliferous), 20 to 21 feet.
Peat, with a creek intersecting it: oak and occasional yew said to occur.

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Littleport Plains.

Southern side.

Peat, 4 feet.
Gravel, 0 to 2 feet.
Boulder clay, seen to 4 feet.

Northern side.

Silt, 2 feet.
Peat, 2 feet.
Boulder clay, seen to 4 feet.

Grab' Farm, north of Littleport.
(Drain intersecting a creek.)

Clay, 3 feet.
Silt, 1 foot.
Peat, seen to 2 feet.

Black Bank Station.

Peaty soil, 2 inches.
Mottled blue and brown clay, with flints, 3 inches to a foot.
"Hoddy" peat, a foot.
Dark brown peat, dug to 3 feet.

The upper two beds are probably the result of cultivation.

Horse Moor, March.

Sand and clayey silt, 5 feet.
Black peat, 2 to 4 feet.
Clay, seen to 3 feet.

Sutton St. Edmund's Parish.
(Rev. E. Trollope.)

Peat.
Silty clay, 2 feet.
Peat.

Murrow.

Red clay, 1½ to 3 feet.
Peat, 3 to 9 inches.
Clay and silt (fossiliferous), opened to 15 feet.

Bishop Lands, near Murrow.

Peat, 4 feet.
Gravel, not bottomed, 4 feet.
This section is doubful; clay probably intervenes between the two beds.

Guyhirn. At the junction of the road from Tholomas Drove.

Warp or silt, 2 feet.
Clay, a foot.
Peat.

Wisbech St. Mary's.

Sandy silt, 1 foot.
Peat, 3 inches.
Clay, 2 feet.

Wisbech, Andrews' Brickyard.

Silt, 1 to 2 feet.
Clay, 3 to 5 feet.
Peat, 5 inches.
Clay, 2 feet.
Silt, full of water.

Wisbech, Brickyard near Railway.

Silt, 1 foot.
Clay, 6 feet.
Peat, 7 inches.
Blue clay, 2 feet.
Silt, in which live prawns occurred, see p. 135, opened to 6 feet.

Elm (closed some years ago).

Silt, 2 feet.
Clay, 4 feet.
Peat, 1 foot.
Silt, 2 feet.
Clay, not pierced, 17 feet.

Walsoken.

Silt, 0 to a foot.
Clay, 5 feet.
Turf, with trees, 6 inches.
Clay, 6 feet.
Silt at bottom of pit.

Emneth.

Clay, 2⅓ feet.
Peat, 2 feet.
Clay and silt at bottom of pit.

Tyd St. Giles.

Clay, 3 feet.
Peat, 2 inches.
Clay, 2 feet.
Peat, 3 inches.
Clay, opened to 15 feet.

Walpole St. Peter.

Clay, 4 feet.
Peat, 2 inches.
Clay, 3 feet.
Blue silt at bottom of pit.

Tilney St. Lawrence.

Silty clay, 3 feet.
Peat, 2 inches.
Strong blue clay (fossils), 3 feet.
Peat (wood), 4 inches.
Blue sandy silt, 3 feet.

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Denver Sluice. (C. B. Rose. *Phil. Mag.*, ser. 3, vol. vii. p. 173.)

	Feet.
1. Light brown sandy loam [warp]	14
2. Peat	2
3. Blue clay, inclosing roots and small portions of peat	2
4. Peat, similar to No. 2	3
5. Similar to No. 1, but somewhat more argillaceous*	2
6. Dark ferruginous sand	3
7. Oxford clay, dark blue, and very tenacious	5½

* "Immediately beneath the peat on the surface of No. 5, a farthing of Charles II. and a pair of scissors were found." [These afford no proof of the modernness of the deposits, as they were evidently lost by the early drainers.—S. B. J. S.]

Salter's Lode Sluice, S.W. of Downham Market.

Clay, 0 to a foot.
Peat, 4 to 6 feet.
Clay, seen to a foot.

Salter's Lode Sluice (foundation). (From Elstobb ?). See Rose, *Geologist*, 1843, p. 74.

Silt, 10 feet.
Moor (peat) firm, 3 feet.
Bluish gault (clay) with roots of reeds.
Moor (peat), very firm, 3 feet.
Whitish clay.

Nordelph Mill.

Peat, 4 feet.
Light-blue clay, 3 feet.
Peat, seen to a foot.

Modney Bridge, Hilgay.

Soil, a foot.
Sand in pockets, 0 to 2 feet.
Clay (boulder), seen to 12 feet.

Fordham. Ditch by the side of Railway, nearly a mile E.
Very thin peat, and then (eastward) patches of very thin gravel over clay.—(W. W.)

Middle Level Outfall. (? Wiggenhall St. Mary.)

Silty clay (fossiliferous), 2 feet.
Peat, 2 feet.
Strong blue clay (fossiliferous), seen to 4 feet.

Road from Stow Bridge to West Head, angle of road to Marshland Cut.

Silt, 6 inches.
Peat, dug for fuel, 2 feet.
Silty clay (fossiliferous), seen to 2 feet.

Watlington.

Ditch, where crossed by the railway, more than half a mile southward of Magdalen Road Station.
Clay, over peaty earth, over gravel?—(W.W.)

Lynn, Eaubrink Cut. C. B. Rose. *Phil. Mag.*, ser. 3, vol. viii. pp. 35, 36, and *Geologist*, 1843, p. 75.

	Feet.
Soil and brown clay with sand	4
Blue clay, a brickearth, with freshwater shells in abundance	3
Peat, containing bones and horns of ruminants	2 to 2½
Blue clay like that above and with like shells	8
Peat, with alder and hazel bushes. The lower portion clay, containing roots of marsh-plants	3
Dark blue clay, a marine silt, with shells in abundance, not cut through.	
	20

Lynn.

The following sections are additional to those given by Mr. Skertchly, all but the first having been made since his work in the Fenland was done.—(W. W.)

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Brickfields, called Sayer's Marsh, south of the town. (C. B. Rose, *Geologist*, 1843, p. 76.)

Brownish loam, with marine, freshwater, and land shells, 2 to 3 feet.
Stiff blue clay with like shells, 4 to 5 feet.
Peat ("moor"); with alder, birch, and other woods, and bones of horse ruminants and water-rat, 4 feet.
Shingly gravelly bed.

Presumably this is the brickyard marked on the map, about a mile south of the Railway Station.

On the eastern side of the road, half a mile S. of E. from the South Gate, I saw brown loam over peaty earth.

Nar Valley Drainage Works, east of the Marshland Free Bridge.

Silt and peat, to a good depth; with shells, chiefly marine (cockles, &c.), but in places a few freshwater (*Spherium, Planorbis, Limnea*).

The works for sewers in Lynn, by East Gate, the Railway Station, &c. in 1883 showed the usual alluvial section of clay, more or less sady, partly peaty, and of peat. Near the station some bits of shell were seen, but could not be determined. In parts there was a good deal of made earth, and also, in the upper part of the cuttings, the brown loam that forms the surface hereabouts.

New Dock, 1882. Western side (see also p. 141).

Loamy earth; 4 to 6 feet, or more.
Fine sand, bedded and false-bedded; in the bottom part with long thin layers of shingle (chiefly one layer); about 12 feet.
Shingle, with layers of sand and some pieces of Kimeridge Clay; full of sea-shells and with many bones; ? 8 feet.
Bluish-grey Boulder Clay, bored into to the depth of 30 feet.

At the eastern side of the lock-entrance the Boulder Clay rises up, the shingle thins out, and above comes a pale greenish-grey clay, with broken shells and twigs, which rises up to the south-eastern corner.

At the north-western corner loam and silt scoop down, through sand, to shingle.

These docks are along what was formerly the river-channel (as shown on the old Ordnance Map), before the great cut to the west was made, and so the sections above-noted are in very recent deposits, for the most part.

Fossils and Works of Man.

A list of fossils from the Peat is given on pp. 320, 321 of the Fenland Memoir, but without any localities; so that it seems best merely to refer to it here, as a general list.

In that Memoir (pp. 182, 321, 322) there are unfortunately two different and apparently irreconcilable lists (there being only six entries in common) of the fossils of the Fen Silt, also without localities.

Yet a third, and also to some extent a different list, has been given in "The Fenland Past and Present," p. 342 (1878).

Under these circumstances it will be best to enter here only such occurrences as have been recorded in our district.

Megaceros hibernicus and *Castor europæus* have been recorded by Sir R. Owen, as found "in a subturbary deposit at Hilgay."*

In 1883 Mr. E. T. Newton visited the Wisbech Museum and noted remains of the following vertebrate species there:—

Bos and *Capra*; Shire Drain, Tyd St. Mary.
Cervus elaphus; Clay-pit, Lynn Road, Wisbech.
Sus scrofa; Manea Fen and Feltwell Fen.
Cetacean; Clay under Peat, March Fen and Upwell Fen.
Pike; Southrey Fen.

* *Quart. Journ. Geol. Soc.*, vol. iv. p. 44. (1848.)

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Reindeer has been recorded by Mr. Skertchly "at 5 feet in Feltwell Fen."*

Prof. H. G. Seeley has recorded that "at Wisbeach St. Mary's, three miles west of the town, in a clayey bed at a depth of fifteen feet, were found —*Tellina obliqua, Cardium edule, Scrobicularia piperata*, examples of which are preserved in the Wisbeach Museum."†

In 1850 Mr. W. J. Hamilton gave the following list of species of Mollusca and Ostracoda from the Shell Marl along the railway between Littleport and Downham Market (see p. 132). The latter were determined by Prof. T. R. Jones, who has kindly revised his list.

Mollusca.

Bithinia tentaculata, *Linn.*
Helix pulchella, *Müll.*
Limnæa peregra, *Drap.* [*Müll.*] 2 vars.
Limnæa stagnalis, *Drap.* [*Linn.*]
Physa fontinalis, *Drap.* [*Linn.*]
Planorbis carinatus, *Müll.*
„ lævis, *Alder.* [=P. glaber, *Jeffr.*].
Planorbis, marginatus, *Drap.*
„ vortex, *Müll.* [*Linn.*].
Valvata cristata, *Müll.*

Pisidium obtusale, *Lam.* [var. of P. pusillum].
Pisidium pusillum, *Turton* [*Gmel.*].

Crustacea. Ostracoda (Entomostraca).

According to G. S. Brady and M. Norman.‡ Words in brackets as in the original list.

Candona candida, *Müll.* (C. lucens).
„ pubescens, *Koch.* (Cypris setigera).
Cypris incongruens, *Ramdohr* (C. aurantia).
Cypris lævis, *Müll.* (C. minuta).
Herpetocypris (Candona) reptans, *Baird.*
Ilyocypris (Cypris) gibba, *Ramdohr.*

The peat of the Fenland is of interest as containing relics of man's work, which may fairly be noticed here, as they mark the age of the deposit in like way to that in which fossils serve in other formations.

Fig. 38. *Flint Arrow head from Chatteris.*

Our first notice, by Mr. Skertchly (from the Fenland Memoir), refers to Fig. 38, which is from a beautifully chipped arrow-head, found in buttery clay, at a depth of 4 feet, by Mr. Fryer, of Chatteris, in whose collection it is. It is of black flint and singularly perfect. The chippings are exquisitely fine, and the whole surface is worked over.

Mr. Cameron notes that stone and bronze celts have been found at Wretton and Dereham Fens.

Mr. W. Marshall has "noted the occurrence of a shallow flat-bottomed boat, formed of one piece of oak timber, in the banks of the River Ouse, between Magdalen Bridge and Denver Sluice [a rather unprecise locality]. The peat-bed in

* The Fenland Past and Present, p. 353.
† *Geol. Mag.*, vol. iii. pp. 498, 499. (1866.)
‡ *Sci. Trans. R. Dublin Soc.*, ser. 2, vol. iv. pp. 69, 73, 84, 98, 101, 107. (1889.)

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which it occurred, known as the "Moor Bed," was 4 feet thick, and covered by an undisturbed deposit of silt."*

In making the new dock at Lynn (see p. 139), a great quantity of remains of human work was found, as would naturally be expected; such as fragments of pottery of various ages. I saw also a bone borer, a bone flute, two wooden combs, a celt, and a beautifully worked arrow-head. The most characteristic fossils, so to speak, were *shoe-soles*, of which I found several, and must have seen at least 120. Nearly all were of a pointed form, had been worn, and had marks of stitching. A single specimen was of a very broad-toed pattern, suggestive of having been made for the very broad-footed plate armour of Tudor times. Strange to say, these soles were without their proper accompaniment of uppers, only one small representative of that part of the article having been found toward the close of the work, and that apparently of later date than the pointed soles, which were clearly of considerable age.

Probably the Museums of the Fenland and its borders contain a number of specimens of man's work, of various ages, from the Fen beds. Some flint celts, from beyond our district, are figured in the Fenland Memoir, and very many specimens are described by Sir J. Evans,† though they are not noticed as having been found *in* any of the Fen beds, and are probably surface-specimens.

Tributary Valleys.

Of the Alluvium of the tributary-streams there is very little to be said, sections being rare, and most of the alluvial tracts narrow.

Mr. Cameron notes that "the railway-cutting, some 400 yards or more west of the Stoke Ferry Station is in peaty sand, very full of freshwater shells, of species such as are now living."

The same observer says that "the peat extends far inland, from the Methwold Fens, up to Oxborough, Eastmore and Barton Fens," in both branches of a valley tributary to that of the Wissey, near Stoke Ferry.

Of the Nar Mr. Hawkins writes as follows:—

"The narrow Alluvium down to nearly two miles below Narborough is nowhere a quarter of a mile broad; but then it opens out into a broad fen, in which the peat is said to be of great thickness between Shouldham Warren and Wormegay, and near the junction of the Wormegay Drain with the Nar."

"The surface-level of the peat has been much lowered of late years by the drainage, for as the peat is laid dry it not only contracts, but actually decomposes and disappears. On the northern side of Wormegay the surface has been lowered in this way as much as four feet, within the memory of persons now living (1883), ground formerly covered with peat being now entirely free from it. Messrs. Hoff, of Wormegay, gave much information relating both to the peat and to the Nar clay."

"There are water-meadows at West Lexham and at Castle Acre."

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* *Proc. Norwich Geol. Soc.*, part iii. p. 74. (1879.)

† The Stone Implements . . of Great Britain.

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The ditches by the sides of the Eastern and Midlands Railway across the marsh of the Middleton Valley showed clayey alluvium.

The Alluvium of Leziate Fen was hard to map about a mile eastward of the ruins of the church, and for two reasons:—part of it, a whitish marl, seems to rise somewhat above the marsh-flat, and the old map cannot well be described as correct.

By the side of the old line of the Eastern and Midlands Railway lower down the valley there is peaty earth over sandy earth half a mile west of Weavling House, whilst at and below Bawsey peat or peaty earth occurs.

ADDENDUM.

The following escaped notice in the Fenland Memoir. Although it refers to a tract just outside our district, to the west, it is well to reproduce it here.*

"In an old lacustrine deposit at Whittlesea . . , which is overlaid by five or six feet of marl, the following Ostracoda were found":—

Candona albicans, *Brady*.
,, candida, *Müller*.
,, compressa, *Koch*.
,, lactea, *Baird*.
Cypridopsis Newtoni, *Brady* and *Robertson*.
Cypris gibba, *Ramdohr*.
,, lævis, *Müller*.
,, ovum, *Jurine*.
,, reptans, *Baird*.
Darwinella Stevensoni, *Brady* and *Robertson*.

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* A Monograph of the Port Tertiary Entomostraca of Scotland, including species from England and Ireland. By G. S. Brady, Rev. H. W. Crosskey, and D. Robertson, p. 108, Palæontograph. Soc., 1874.

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CHAPTER 15. ECONOMICS.

Building Materials.

Stone.

The carstone of the *Lower Greensand* is used a good deal in building, as at and around Downham Market, where it is of a fissile kind, splitting into thin slabs, unlike the massive sort in the neighbourhood of Hunstanton, in the tract to the north (Sheet 69).

Carstone is or has been worked more largely at West Bilney, East Winch and Middleton (see pp. 15–17), some of the stone there being more massive.

The *Chalk* has been a good deal used for building, and its flints have always formed a handy and lasting stone, whether got direct from the Chalk or from the various Drift beds, of which they form so large a part.

Mr. Skertchly notes that the "moderately hard chalk got near the river about two miles westward of Brandon comes away in pieces about the size of bricks, and is used for walling."

Mr. Cameron says that "near Hilborough chalk has been got for building, the roadside-pit by Rowley Farm affording the best material."

Of the Lower Chalk worked at Marham Mr. R. C. Taylor has said that it is "sufficiently hard for building, the church, the adjoining abbey, and a tomb within the church with recumbent figures, having been principally constructed of this material."*

Mr. H. B. Woodward has contributed the following remarks on the architectural uses of chalk, written to his grandfather, Mr. S. Woodward, by Mr. C. B. Rose (4th February 1830):—

"From an examination of the monastic and castellated remains of this neighbourhood (Swaffham), it appears to have been extensively used for *inside* work, not merely for the inner walls dividing the building into apartments, but the inner portion of the outer walls; the walls of the Castle at Castle Acre are constructed of Chalk, cased exteriorly with flint or other less perishable material."

"Chalk still continues to be employed in the construction of barns, cottages, farm-houses, garden-walls, &c.; the hard grey chalk (that without flint) is to be preferred, but the chalk with veins of flint is occasionally used and found to answer; walls constructed of it remain damp a long time, I believe. It is necessary that the mortar is of the best quality, to insure the durability of the building; and equally necessary that the wet should be prevented from insinuating into the work; for instance

* *Trans. Geol. Soc.*, ser. 2, vol. i. p. 378. (1824.)

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to insure the durability of a wall it is necessary to have a good coping of brick or tile to protect the upper surface."

"The method of using the chalk is as follows: it is raised by quarry-men in largish masses and allowed to weather; the hardest, and that without flaws (for some portions are disposed to part into laminæ by the frost) is chosen, and squared into the form of a brick, but somewhat longer and about twice the thickness; these forms are then used, as if they were bricks, for the outer and inner layers of the work, the space between being filled with irregular fragments."

See also pp. 38, 43.

Lime, Whitening, etc.

Chalk is burnt for lime in many places, and indeed is the only source of that product in the district; but there are no works of great importance. Both lower and higher beds are used.

MR. CAMERON notes that "the Hilborough chalk was formerly used for whitening, and a pit is known as the Whitening Pit." See also, p. 38.

An attempt was made (soon after I left Lynn) to use the ferruginous beds (iron-oxides) around springs from the Lower Greensand, eastward of that place, for the manufacture of dry pigments; but the Company formed for that purpose soon collapsed. Small heaps of the material were to be seen near New Spring (see p. 18).

Bricks, etc.

The *Oxford Clay* has been worked at Forty Foot Bridge, Ramsey, in the south-western corner of the district (see p. 7).

The *Kimeridge Clay* is worked at March, Downham Market, Watlington, and West Winch (see p. 8).

The thin clayey middle division of the *Lower Greensand*, which occurs only at the northern margin of our district, gives the sole supply to the kiln on the eastern side of Brow of the Hill, Ash Wicken, where pipes, tiles, and special bricks are made, as well as the common bricks.

The *Gault* is too calcareous in our district to yield a good brick-clay, and no brickyard was seen in it. There seemed however to have been one in the more clayey bottom part of the formation at Grimston (see p. 25).

The various clayey and loamy members of the *Drift* are worked in many places, as may be seen from the number of brickyard-sections described above.

MR. CAMERON notes that "at Hilborough the bricks for the Hall were made from the Boulder Clay, in the meadow in which stand the ruins of the chapel."

MR. H. B. WOODWARD says that at an old brickyard at Rougham (see p. 111) "pots and tiles, some of an ornamental kind, had been made [? from Boulder Clay], as well as bricks; but the manufacture had been given up (1883)."

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There is one of these deposits which was formerly worked, but is now no longer, the marine shelly clay of the Nar Valley (see p. 81). Mr. Rose has said of this, at West Bilney:—"The yellow loam [at top] burns into a red brick; a portion lying between the loam and the blue clay, and probably a mixture of the two, produces a mottled brick; and the blue clay . . becomes a fine white brick."*

Again, in speaking of a brickyard S. of East Winch, he noted a loam "that is used to make a *red* ware"; whilst "the blue brick-earth lying beneath this burns into an excellent white brick."†

The difference in colour and character of the beds is owing to weathering, resulting in peroxidation of the iron-salt that forms the colouring-matter.

In describing the *Fen Silt*, in the Fenland Memoir, Mr. Skertchly has said that the clayey variety is what brickmakers call "light clay," which shrinks considerably on firing. This clay is always mixed with sand or warp for brickmaking, but even then shrinks greatly. He gives the following examples, from our district, and adds that "the bricks are very poor, being soft, friable, and often ill-shaped and cracked. They are generally burnt in kilns, but often in clamps."

	Size of Mould.	Size of Brick.	Shrinkage per cent.
Wisbech, Andrew's Brickyard -	$10 \times 5\frac{1}{4} \times 3\frac{3}{4}$	$9 \times 4\frac{1}{3} \times 2\frac{3}{4}$	43·4
Walsoken Brickyard - -	$10 \times 5 \times 3$	$9\frac{1}{2} \times 3\frac{1}{4} \times 2\frac{3}{4}$	43·3

The figures stand for inches.

My own experience is limited to the loamy variety of the Fen Silt, which is often a fair brickearth (for common bricks), being not unlike that of some Valley Drifts. I have seen it worked 1¼ miles east of Wiggenhall St. Peters and at Lynn.

The practice, so common in parts of the Eastern Counties, of making clay-blocks from the Boulder Clay, which are merely dried before being used for building, has been noticed on p. 58.

Applications to Land.

The sources of *Road-metal* in our district are the various gravels of the Drift, and the stones often found liberally scattered over the surface. These latter have the advantage of having been hardened, or toughened by exposure. Some of the hard Chalk might be used, at all events to give a more binding character to

* *Phil. Mag.*, ser. 3, vol. ii. p. 31. (1836.)
† *Geol. Mag.*, vol. ii. p. 10. (1865.)

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other material; but I have no recollection of having seen it used. I believe that the carstone of the Lower Greensand is occasionally used on bye-ways.

Of material used as *dressing to land*, MR. J. TRIMMER has noticed the following: "In a hollow in the chalk near Castleacre is a blue clay containing lumps of chalk" (Boulder Clay), which has been used "on a loam, by no means very light, with great benefit, particularly visible in the subsequent crops of clover." And again, "The clay of the Nar with its beds of . . shells." "The fresh-water clay and calcareous sand of Gaytonthorpe," and the Chalk.* It is doubtful however whether any of these are now used, at all events beyond a very small extent, in the cases of the Boulder Clay (see pp. 51, 58) and the Chalk. Gault has also been used (see p. 24), and Alluvial Clay (see pp. 123, 152).

Phosphatic deposits, in the form of layers of nodules, occur in the Cretaceous beds of the district; but in one case only, near West Dereham, have these been found in quantity enough to be workable (see pp. 11–14), and now I believe this industry has ceased.

Small nodules have been seen in thin layers, and more or less scattered, in various parts of the Lower Greensand; but they seem poor in quality as they are in quantity. Where worked these nodules occur at the top of the formation and in the base of the overlying Gault, the latter set being of a different character.

Poor nodules have been seen at the base of the Chalk at Shouldham, and probably occur elsewhere; but nothing like the marked Cambridge bed has been seen.

FUEL, ETC.

The peat of the Fenlands yields a local supply of fuel, which is generally got by the digging out of vertical blocks. MR. SKERTCHLY has however noticed an exception to this in our district, remarking that in some places, as at Salter's Lode Sluice, at the junction of the Well Creek with the River Ouse, south of Downham Market, the peat is not compact enough to hold together when cut out vertically. In such cases it is dug from the trench by means of a *pricker* which is a sharp iron spade, and a broad *becket* (or shovel).

The blocks are cut with the length horizontal, instead of vertical, the pricker being used for the vertical face-cuts and the becket for the inside-cuts and for the horizontal cut. (Fenland Memoir.) Further details have been reproduced in the Memoir on the district to the south, where the largest turbaries are.†

MR. CAMERON notes that, "in 1883, peat was dug for fuel at Hilgay, eastward of Severall's House (Methwold Common), and a little north-westward of Methwold, as well as, on a smaller scale, at Barton Fen."

* *Journ. R. Agric. Soc.*, vol. vii., pt. ii. pp. 479, 480. (1847.)
† The Geology of Parts of Cambridgeshire and of Suffolk, pp. 106, 107. (1891.)

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Mr. Hawkins records that, in the same year, "peat was dug in the 'Turf Fens' N.W. and N.E. of Marham; and a great deal was formerly dug in the 'Turf Fen' west of Shouldham Warren."

In places in the Lower Greensand tract of the northern part of our district there are relics suggestive of an industry of which I have seen no written record, and which therefore is presumably of great age and has been long abandoned.

In a field near Ash Wicken (unfortunately I can find no note of the exact spot; but I think that it was not far from the railway from Lynn to Swaffham) I saw a great number of pieces of slag, which seem to have been left from iron-smelting, and afterwards Mr. Hawkins showed me a like occurrence in Wormegay, eastward of the village.

One is led to think therefore that in long past times some of the ferruginous beds of the Lower Greensand may have been worked for iron, for local use. The ore used must have been a poor one, and one is not tempted to speculate on the return of this industry to the district.

Water.

As far as we know no boring in the district has pierced the *Jurassic Clays* and reached the limestones beneath, though unsuccessful borings at March and Lynn (see pp. 154, 158) have been taken to some depth in the clays. At Downham Market (see p. 157) a fair amount of water has been got from stone-beds or from sandy layers in the Kimeridge Clay.

No public supply is taken directly from the *Lower Greensand*, though it contributes to the stream which as yet supplies Lynn (see p. 147); and we have records only of three wells carried through overlying Cretaceous Beds to this permeable formation, at Stoke Ferry, West Dereham, and Narborough (see pp. 158, 159). A good deal of water is thrown out from the Lower Greensand, but much of it must be ferruginous. Some of the low-lying tracts are much water-logged, as around Leziate Fen.

As there are several villages and the town of Downham Market chiefly or partly on this formation, there must be a great number of private wells either wholly in it or carried through Drift, and sometimes through a slight depth of Gault, to it. Of its water-yielding power, however, we have little information, from the absence of any large work, and it is doubtful whether wells in the Lower Greensand are not often too near cess-pits and other sources of pollution.

The *Chalk* is the chief water-bearing formation, both from its wide outcrop and from its thickness; and yet there are only two public supplies taken direct from it. The first is at one of the

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Marham Springs, the water of which is taken to Wisbech, supplying many Fenland villages on the way and the town of March. MR. HAWKINS remarks that these springs are hardly free from some risk of pollution (see p. 149). The second is at Swaffham, which is supplied from a well. In this case the water is returned to the Chalk, about 2 miles S.S.E. of the Waterworks, in the form of sewage, which is poured into an old chalk-pit on the eastern side of the road in the valley by the junction of Swaffham Heath and Pickenham Warren. This matter I have had occasion to refer to before.*

The stream which supplies Lynn originates in a set of Chalk springs (see pp. 149, 150), but this water is fouled partly at its origin and also on its way to the town, and it is to be hoped that a scheme of MR. E. J. SILCOCK, the Borough Engineer, for securing the pure spring-water and carrying it in pipes to Lynn will be adopted.

It is now some years since the need of such a work was strongly alluded to, and it was suggested that the occurrence of a serious epidemic might bring it about.† The epidemic came in 1892, in the shape of an outbreak of typhoid fever, preceded by one of diarrhœa, which was traced to the fouling of the water-supply.‡

Chalk-water is of course largely taken by private supplies, there being so many villages either on this formation or on Drift overlying it.

The head-waters of the streams in the eastern part of our district are in the Chalk, whether bare or covered by Drift, and there are many marked springs, some of which will be noticed, most perhaps being in the Lower Chalk. As we were unable to trace a division between the Middle and Upper Chalk, one can only say that the former of these certainly, and the latter probably, gives out springs.

The outflow of water from the Chalk depends but little, if at all in our district, on the divisions of the formation: it is determined simply by the relation between the surface of the ground and the saturation-level, the latter being the level to which water percolating through the rock sinks, until it reaches a point where the Chalk is charged with water and can hold no more. This saturation-level is naturally irregular, from the frictional resistance to the flow of water horizontally through the mass of the Chalk, and it roughly follows the changes in surface-level, though not varying to the same extent as the latter: it is higher under the high grounds, though there at a considerable depth, and it falls more or less gently to the low grounds, though there nearer the surface: it is greatly affected by seasonal changes, falling after dry weather, rising after wet, and the more

* *Trans. Sanitary Inst.*, vol. viii. (1887.)

† *Proc. Norwich Geol. Soc.*, pt. viii. pp. 286, 287 (1884), and *Geol. Mag.*, dec. iii., vol. i. p. 24.

‡ DR. R. B. LOW, Report to the Local Government Board on an Outbreak of Typhoid Fever in the Borough of King's Lynn, Norfolk. 31 Aug. 1892.

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so the higher the ground. Where the surface sinks below the saturation-level, there the water bursts forth, and, as the saturation-level is a very varying one over large tracts, springs break out at times much higher up the valleys than at others, the lowest springs being in constant flow, though their yield varies.

Less than a mile S. of E. from Fouldon church the site of a spring is marked by a small elliptical enclosure on the map.

A third of a mile E.N.E. of West Dereham Church there is a spring, from near the base of the Chalk, on the southern side of the road, marked in a like way.

Mr. Barrow contributes the following notes:—

"About North and South Pickenham powerful springs issue just above the stream-level, the one half a mile southward of the Hall, South Pickenham, being especially strong and forming a deposit of tufa. Another spring occurs lower down the valley about two thirds of a mile N.E. of Hilborough House. In the early spring the boundary of the alluvium is only a few feet above the saturation-level of the Chalk."

"A tributary of the Wissey rises in a powerful spring some way above Cley Hall (Cockley Cley); so that the saturation-level in the Chalk must be fairly high here. This spring deposits much tufa, and is not known to run dry."

"At Drymere Pit, about two miles S.W. of Swaffham, water flows out after wet weather and a large covered drain has been made to carry off the water, which often used to flood the little valley in the rainy season. In summer however the outflow is lower down, being near the fens in the other tributary, near Shingham and Beachamwell."

"At Wood Farm, close to Swaffham, a well 130 feet deep runs dry in summer. Another well, 60 feet deep, close to the railway-bridge half a mile east of Swaffham, is never dry."

Mr. Hawkins notes the following springs along the valley of the Nar:—

"Half a mile south of Emanuel Farm, Castle Acre, a spring rises in a field on the northern side of the road, just on the edge of the Drift (clay)."

"Springs also rise on the western side of the road about half a mile E.S.E. of South Acre church."

"On the northern side of the river rather more than a quarter of a mile above the bridge at Narford, there are many copious springs, the quantity of water from which is so large that they form one of the chief sources of the Nar."

"Some fine springs may be seen on the western side of the railway a mile S.E. of Narborough Railway Station."

"A spring rises at the edge of the 'Turf Fen' half a mile S.W. of East Gate, not far from the Fox Inn (between Narborough and Marham)."

"Half a mile nearer Marham are the springs that give the supply for the Wisbech Waterworks. These rise on the northern side of the road a little below a farmyard and a group of cottages: the water comes from the base of the Chalk in large quantity."

"Near Marham church there is another fine spring, on the western side of the road across the Fen to Pentney Mill."

According to information given by a farmer, in 1883, the strange hollows in the lower ground of East Walton, which have probably been caused by Chalk-springs, were known to increase; and he had noticed sinking of the ground lately, after hot weather.

The tract between Walton Common and Gaytonthorpe Common is peculiar. It is partly boggy, with sandy mounds and roundish ponds that are surrounded by banks (like earthworks). These lakelets seem to be due to the sinking in of the beds, so that the surface is then below saturation-level and water consequently appears. They are in fact small Meres.

At Gaytonthorpe water rises close to the top of the Lower Chalk.

At and south of Grimston is an interesting set of springs, from the base of the Chalk, forming the head-waters of the stream that flows by Leziate, and which is taken for the supply of Lynn.

The most southerly, and taken together the most powerful, of these springs are at Well Hall, northward of Gayton. These break out close above and at the farm, one spring indeed oozing out from under the northern wall of the

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farm-buildings, and all but the higher springs being polluted by the drainage from the farmyard, a lamentable state of things, considering the natural purity of the water.

Less than half a mile to the north is the Sow's Head spring, in a field and away from sources of pollution.

At the village of Grimston are other springs, the chief ones being just west of the church, and separated only from the churchyard by a road. Here, therefore, as at Well Hall, human ingenuity has done about its worst for the water, most of which must flow at no great depth underneath the churchyard, where "the rude forefathers of the hamlet sleep," before it comes to the surface, and is used by some of their descendants or successors.

The following gaugings of these Grimston springs have been kindly given by MR. E. J. SILCOCK, the figures standing for gallons a day :—

	Well Hall.	Sow's Head.	Church.
Minimum discharged observed (by him), at the end of August, 1887 - -	612,000	166,500	460,000
On 13 January 1893 - - -	1,267,000	278,000	—
„ 25 March 1893 - - -	1,452,000	307,000	—
„ 20 May 1893 - - - -	1,020,000	459,000	—
„ 10 July 1893 - - - -	736,000	368,000	—

This does not take into account other springs in the village. In a Report to the Corporation of Lynn, dated 18 January 1893 (in which the first two sets of the above figures are given) MR. J. MANSERGH says that probably in the driest seasons 700,000 gallons a day may be relied upon from Well Hall and Sow's Head Springs together.

The increase of the Sow's Head Spring after 25 March 1893, at a time when it should have decreased, is owing to works carried out by MR. SILCOCK, in order to find whether the discharge could be increased and to what extent. He has kindly communicated to me his Report to the Water Works Committee of the Corporation on the result, and from this, which is dated May 26, the following particulars are taken.

A trench was cut eastward from the spring into the hill-side, for 50 yards, when the chalk was found to be harder than was expected and the work was stopped. The gauging of March 25 was a few days after the work had been begun and before the discharge had been affected by it. The yield went on increasing afterwards to the extent of about 50 per cent. It should be borne in mind that a long drought, broken by only very few slight showers, had continued since the first week in March, the effect of which would be to reduce the yield, and it will be seen that the Well Hall Spring had decreased 30 per cent. Assuming that the Sow's, Head Spring would have decreased at the same rate, as it probably would have done, if it had been left alone, its discharge on May 20 would have been 215,000 gallons a day and the increase, resulting from the work done in opening out the spring, would have been 115 per cent., or in other words the yield would have been rather more than double.

MR. SILCOCK also tells me that the heavy rainfall of February

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affected the springs before the 6th of March. This quick action (as compared with what happens in many Chalk tracts) is owing to the gathering-ground being all near the springs, which are fed only by the rain falling on the gentle slope of the broad escarpment.

The various gravels and associated sands of the *Drift* are of course largely used for private supplies, many villages being on them, or partly so. As long as houses are not too near together and cess-pits are at a reasonable distance from wells these supplies may be good; but it is hardly to be expected that such a state of things is too common.

The following notice of some supposed thermal springs near Chatteris is taken from the Fenland Memoir, with some change (Professor Judd's remarks being now quoted).

Mr. F. W. Harmer has called attention to the high temperature of the water from certain wells in the neighbourhood of Chatteris.*

In this paper Prof. Judd stated "that the secondary strata which underlie the alluvial deposits of the fens are in the adjoining counties considerably faulted and dislocated; but whether in this way the water described may be in communication with the central heat of the earth, or whether the matter is to be explained by chemical causes, he does not . . offer a decided opinion."

With the former view, Mr. Skertchly says, I cannot agree, for it would be singular that faults in hard beds, such as the Oolite limestones, much more favourable to the production of open fissures than the tenacious Oxford and Kimeridge Clays (on the latter of which Chatteris is placed), should give rise to cold springs only. Nor do I think that the district in question is faulted. Before the survey of the area was undertaken faults were believed to be much more numerous than they were found to be; and although I believe a great fault throws down the beds on the Lincolnshire border of the Fens, and from which a series of fine springs issue, yet the waters so produced are always cold. Again, these warm springs are all very shallow, so far as is known, springing from the gravel at a depth of about 10 feet, and we must suppose either that the warm water has saturated those beds, or that the wells have accidentally struck the neighbourhood of the fissures in each case. The area over which the warm springs are found, too, seems to be against such a theory, as we should expect them to occur along lines and not over a wide area. Finally, as the Rev. O. Fisher has shown,† warm water is not infrequently pumped from farm-yard wells where they are shallow, and this I have verified in the neighbourhood of Ely, far away from any fault. It is only fair to state that Mr. Harmer advanced this idea in his paper, but was driven from his position by the chemical arguments of Mr. F. Sutton, of Norwich, though he still considers the question unsettled.

Mr. Harmer having communicated the MS. of his paper, most of it was printed in the Fenland Memoir, and is now reproduced.

"The first of these farm-yard wells (which I will call No. 1) that I examined is in a yard belonging to Mr. W. Lyon, four miles east of Chatteris, and three quarters of a mile west of Welche's dam. The surface of the land at this point is, I suppose, slightly below the sea-level, and apparently about two feet below the level of the water in Vermuyden's Drain. The ground is consequently saturated with water, it being necessary only to dig down a spade's depth or so to reach it, and the ditches are full of water to about two feet from the surface of the land. The temperature of the water from the well on the 14th March 1870, I found to be 69° F., that of the air at the same time being 39° F.

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* Abstract only, in *Rep. Brit. Assoc.* for 1870, *Sections*, p. 72. (1871), and letter in *Geol. Mag.*, vol. viii. pp. 143, 144. (1871.)

† *Geol. Mag.*, vol. viii. p. 42.

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of the water in Vermuyden's Drain 37° F., and of that in the ditches close by the yard 38° F., the water in both cases being covered with ice ⅛ of an inch thick. I was informed that in sinking the well they had passed through, first, 5 or 6 feet of peat, then 1½ feet of clay, on the surface of which and rooted into it are found all over the immediate neighbourhood numerous remains of oaks and willows, and finally a reddish sand, from which at a depth of from 8 to 10 feet, it would seem, the hot water was obtained. This bed of clay, which, underlying the peat, and often of greater thickness than in this case, is so constantly used in the fen for top dressing the land, seems to present one difficulty to the hypothesis that the heat is produced by the decomposition of the manure lying above it. The water is evidently heated only at the bottom of the well, as when one first begins to pump, the water comes out cold, and it is only after continuing to pump for a short time that the hot water makes its appearance. If the manure caused the heat that nearest the surface should be the hottest. Mr. Lyon informed me that though the farm had belonged to him for years, he had never known the water to be otherwise than hot, summer or winter, though in summer the greater comparative heat of the air made it less apparent."

"About half a mile S.S.W. from Mr. Lyon's well is a pump similarly situated, but in this case it was fed from the surface-water and not from the stratum beneath the clay. The water showed no such abnormal temperature as in the last case, though, as might be expected, it was higher than that in the exposed drains."

"At the adjoining yard at Fortry Hall, about half a mile S. of the last, I found the underlying stratum again reached by a pump, (No. 3) situated similarly to the other. Here the heat was 66·5° F. The water from both Nos. 1 and 2 contained very much organic matter (see MR. SUTTON'S analysis)."

"At another farmyard about 4 miles W. by S. from the last, and about 1½ mile S. by W. from Chatteris, at Horsley Fen Drove I tested the temperature of the water from a well (No. 4) similarly shallow to No. 2, and found it to be 51·5° F. I was informed by a man in the yard that shortly before my visit an Abyssinian tube-well had been sunk to a depth of about 6 feet below that which I had tested, and that the water obtained from it had been warm."

"No. 5 well, in a farmyard at Langwood Hill, two miles W. by N. from No. 1, and two miles E. by N. from Chatteris, differs somewhat from the others in being situated on a low outlier of gravel. The water was found to be 71·5° F., and so pure as to be constantly used for drinking purposes by the cottagers. It was 14 feet deep, and entirely in gravel. Allowing for the slight elevation, the water was at about the same level as in Nos. 1 and 3. I visited the place again on June 2nd, when the yard was not occupied by cattle, and found the temperature to be 70·75° F., while that of a shallow ditch close by was 71·5° F., and of the air in the shade 70° F."

"MR. F. SUTTON, at my request, kindly analysed the water from Nos. 1, 2, and 5 wells, and also that of Vermuyden's Drain, and I give below his results."

"I feel, with MR. FISHER, the difficulties of any other than a chemical explanation, but I have called attention to the phenomenon because I think there is a *primâ facie* case for further investigation."

"MR. SUTTON'S analyses and remarks are as follows":—

Number of Samples.	Source.	Temperature at Source.	Total Weight of Solids per Gallon, in Grains.*
[The figures in brackets are those given above by Mr. Harmer.] 1 [1]	Well	69° F.	207·89
2 [3]	do.	66·5° F.	279·5
3 —	River	38° F.	109·62
4 [5]	Well	74·5° F.	60·74

* The residue is after ignition at a low red heat to burn off peaty organic matter, &c.

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"All the samples contained dissolved and suspended peaty matter, but none of them contained more than a mere trace of ammonia or nitric acid. The solid residue left on ignition consisted, in all cases, of carbonate of lime and magnesia, sulphate of lime, chlorides of sodium and calcium, the latter probably derived mainly from sea-water."

"The best water for domestic purposes, in every respect, was No. 4."

"The question to be solved is—What causes the high temperature of the water in the wells? The idea first occurring to me on hearing there was so great a difference of temperature between the wells and the river was that, as the wells seem all to be situated in the neighbourhood of farmyards, a species of nitrification was going on in the soil, of sufficient intensity to produce the rise in temperature—in which case, of course, there would have been some distinct evidence of it in the water itself. Such, however, was not the case in any instance, there being in none of the samples more than a mere trace of nitrates or ammonia."

"Another possible explanation offering itself previous to the examination of the saline constituents was that, the proportion of salts being considerable, some chemical decomposition might be going on between the acids and bases, so as to cause a development of heat. But the qualitative analyses of these salts show that they are the same as exist in all ordinary waters, and are not of such a nature as to result in chemical decomposition. Moreover, the sample of water showing the greatest temperature contains by far the least amount of mineral matters."

"These suppositions failing to throw any light upon the matter, I am constrained to believe that chemistry can furnish no solution to the difficulty, so far, at least, as the local production of heat is concerned."

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APPENDIX I. WELL-SECTIONS.

[Words in square brackets have been inserted.]

CAMBRIDGESHIRE.

Doddington. The Union.

Blue clay. Rock-bed 6 feet thick at the base. 180 feet. (C. Reid.)

March. Railway Station. 1883.

Boring, communicated by Mr. J. S. Winbolt, who also showed me specimens (described in brackets). Fossils determined by Mr. G. Sharman.

——	Thickness.	Depth.
	Feet.	Feet.
Made ground (clay with stones, etc.) - -	11	11
Ballast (shelly gravel) - - - -	1	12
[Kimeridge] Clay (fragments of *Ammonites biplex*? and of *A. cordatus*? at 15 feet), septaria at 65 to 66 - - - - - - -	58	70
[Oxford] Clay, light-grey, rather darker in parts, with septaria at or near top, at 84 to 85½, at 93½ to 95, at 143 to 144½, at 148½ to 150, at 155 to 157, at 167½ to 172, at 174½ to 176. *Gryphæa dilata* at 70 to 76, at 250 to 265 and at 274. *Avicula inæquivalis* at about 128. Some stone, with bits of shell, between 145 and 160. Piece of wood at 249 - - - - - -	214	284

There is some doubt as to the determination of the Ammonites, and unfortunately the specimens have not been kept. *A. biplex* is an Upper Kimeridge species, whilst *A. cordatus* is a Corallian one, though it occurs rarely in the Kimeridge Clay of Yorkshire, associated with *A. biplex*.

The following sections are in more southern parts of Cambridgeshire, the Memoirs on which have been published. It is thought better to print them here than to keep them in MS.

Burwell. 1 near Almshouses. 2 near the Bushell Beerhouse. 3 near Burnt Yard. (Sheet 51, N.W.)

Communicated by Mr. John Brown, Rural Sanitary Inspector (1892).

1, 17 feet above the Ordnance Datum. Shaft 5 feet. Water-level (April 1892) 10 feet above O.D.

2, 25 feet above Ordnance Datum. Shaft 8 feet. Water-level 15 feet above Ordnance Datum. Yield 27 gallons a minute, with a six-inch pump.

3, 18 feet above Ordnance Datum. Shaft 7 feet. Water-level (April 1892) 11½ feet above O. D.

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	1.	2.	3.
	Feet.	Feet.	Feet.
Alluvial soil - - - -	3	2	2½
[Lower Chalk.] Top clunch, loose, soft, easy boring - -	11½	34	16½
[Lower Chalk.] Close white chalk or clunch, very hard boring -	21½	14	21
[Lower Chalk.] White chalk - -	—	touched	—
Gault - - - - -	4	—	touched
Total	40	50	40

Mr. Colchester tells me (1892) that in the garden of his house a boring reached the Lower Greensand at the depth of "about 150 feet, of which 60 feet was through Gault. We have a plentiful supply of good soft water." The thickness assigned to the Gault seems, however, to be too small, and perhaps the upper part of that formation was mistaken for Chalk Marl.

Cambridge. For Mr. W. Warboys. (Sheet 51, S.W.)

Made and communicated by Messrs. Isler and Co.
Supply 900 gallons an hour.

	Thickness.	Depth.
	Feet.	Feet.
Dug well (the rest bored) - - - -	—	14
[Gault] Gault - - - -	132	146
[Gault] Gault with sand - -	7	153
[Lower Greensand.] Rock - - - -	10	163
[Lower Greensand.] Green sand - - -	5	168

Chesterton. Junction Station, Great Eastern Railway. 1890. (Sheet 51, S.W.)

Made and communicated by Messrs. Legrand and Sutcliff.

Water-level 10 feet 10 inches down (May).

	Thickness.	Depth.
	Feet.	Feet.
Dug well (the rest bored) - - - -	—	66
[Gault.] Light[-coloured] hard clay -	62	128
[Lower Greensand.] Green sand - - -	9	137
[Lower Greensand.] Clay and sand - - -	2	139
[Lower Greensand.] Stones - - - -	3	142
[Lower Greensand.] Sand and stones - -	8	150

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SHELFORD. For Mr. A. Sedgwick. About a mile E. of the Railway Station, 1891. (Sheet 51, S.W.)

Made and communicated by MR. G. INGOLD.

Shaft 93 feet, the rest bored. Water-level 91 feet down.

		THICKNESS.	DEPTH.
		FEET.	FEET.
Made earth		3	3
[Lower Chalk.]	Loose chalk with layers of clunch	77	80
	Solid hard clunch	43	123

WHITTLESFORD. Great Eastern Railway Station. 1890. (Sheet 51, S.W.)

Made and communicated by MESSRS. LEGRAND and SUTCLIEF.

Water-level 10½ feet down (July).

		THICKNESS.	DEPTH.
		FEET.	FEET.
Dug well (the rest bored)		—	12
[Drift]	Light-blue clay and chalk	15	27
	Light[-coloured] sandy clay	6	33
	Flint and chalk stones	3½	36½
	Light-blue clay	11½	48
	Sandy clay	6	54
	Hard blue clay	5	59
	Stone	2	61
	Clay	1½	62½
Chalk; no flints; a few shells		87½	150

This section shows the northerly continuation of the Drift channel described *Quart. Journ. Geol. Soc.*, vol. xlvi. pp. 333–340 (1890).

WOOD DITTON. Saxon Street. Public Well. 1892. (Sheet 51, S.E.)

Made and communicated by MR. G. INGOLD.

Shaft 186½ feet, the rest bored. Water-level 183 feet down.

		THICKNESS.	DEPTH.
		FEET.	FEET.
[Glacial Drift.]	White clay	10	10
	Blue clay	50	60
	White clay	3	63
	Red sandy loam	½	63½
	Brown clay	9	72½
	Red sandy loam	2½	75
[Upper Chalk.]	Soft chalk, with layer of flints at the base	60	135
	Clunch	3	138
	Chalk	4	142
	Clunch	3	145
	Chalk, with layer of flints and *Terebratulæ* at 186½ feet	91½	236½

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NORFOLK.

CASTLE ACRE. New Rectory.

Information from the builder, to MR. C. E. HAWKINS.

[Glacial Drift] { Clayey stuff 14 / Shingly - 20 } 34 feet, to Chalk.

CRIMPLESHAM. From MR. REID'S Notes.

Boulder Clay - 28 / Gault [Chalk Marl], 5 } 33 feet.

DOWNHAM MARKET, Railway Station.

Communicated by MESSRS. TILLEY AND SON.

[Through clay] to a thin bed of rock with plenty of water.

DOWNHAM MARKET. Messrs. Wenn & Co., Brewers, &c.

Made and communicated by MESSRS. ISLER AND CO.

Water-level 35 feet down. Yield 360 gallons an hour (from stone-beds ?).

		Thickness.	Depth.
		Feet.	Feet.
[Lower Greensand.]	Shaft (the rest bored) - -	—	7
	Dead sand - - -	10	17
	Dead black sand - - -	12	29
Kimeridge Clay, 187 feet.	Rock - - - -	2	31
	Blue clay - - - -	72	103
	Rock - - - -	6	109
	Blue clay - - - -	99	208
	Blue clay with stone - -	6	214
	Blue clay - - - -	2	216

FINCHAM. Mr. Saunders' house. From MR. REID'S Notes.

Boulder Clay, 10 feet, to Chalk.

GAYWOOD. The Hall. About 1850.

From information on the spot.

[Lower Greensand] { Sand and carstone, about 30 feet. / Hard rock, 10 or 15 feet.

HILBOROUGH. The House. From MR. CAMERON'S Notes.

Gravel - 3 / Blue [Boulder] Clay, 42 } 45 feet.

The garden-well is also through 42 feet of blue clay, and the water rises to 10 feet from the surface.

The well at the Post Office is 21 feet deep, through Boulder Clay or brick-earth.

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LYNN. Mr. Allen's. Nearly opposite St. Nicholas Church. ? About 1812.

C. B. ROSE. *Phil. Mag.*, ser. 3, vol. vii. p. 174, and *Geologist*, 1843, p. 76. In the Fenland Memoir there is an error in the thickness given to the last three beds.

? Shaft 450 feet, the rest bored. [Letter from S. SMITH to Mr. Skertchly.]

—	THICKNESS.	DEPTH.
	FEET.	FEET.
Vegetable soil. [In an account lent me by MR. RUSSELL, of Lynn, got from the man who made the well, this was 7 feet.—W.W.]	—	—
Loam [silt]	7	7
Peat	2 to 2½ (or 3 ?)	9 to 9½
Blue clay	8	17 to 17½
Peat, with alder and hazel	2 to 3	20
Blue clay, with marine silt and shells Blue clay, inclosing nodules of chalk [Boulder Clay]	about 30	50
Oxford Clay, with septaria, &c. [The upper part certainly, and perhaps the whole is Kimeridge Clay.—S. B. J. S.]	630	680

MARHAM. On the southern side of the lane five eighths of a mile S. of the church, and N.E. of the Lime-kiln. Some years ago.

From a letter, by the REV. H. J. SHARPE (to Mr. Jukes-Browne), dated March 1887.

Sunk through chalk (Middle ?, and Lower) - 85 feet.
Bored through Clay [Gault ?] - - - 30 ,,

Whether sand was reached or not could not be said; but the water became troublesome, and the work was stopped.

NARBOROUGH.—Mr. Marriott's, Narborough House. 1884.
Made and communicated by MESSRS. LEGRAND AND SUTCLIFF.
Bored throughout. Water-level 8½ feet down. Supply good.

—	THICKNESS.	DEPTH.
	FEET.	FEET.
Chalk, moderately hard, and hardest near the base; with much water	85	85
Blue hard clay or marl [Gault]	20	105
[Lower Greensand 48 feet.] Sand. Specimen of coarse green sand at 113, with much water	12	117
Green sand and pyrites	27	144
Blowing sand and small white pebbles [? phosphatic nodules]	2½	146½
Blowing sand	6½	153

MR. JUKES-BROWNE remarks that the hardest chalk, at the base, is probably the same bed as the hard whitish limestone of the Sow's Head Spring, Grimston, and of Shouldham (see pp. 33, 35).

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ROUGHAM. Piper Wood.

Sunk and communicated by MR. J. SEAMAN, of Great Massingham.

Drift. { Sand - about 20 feet; Clay - „ 30 „; Sharp sand „ 50 „ } about 100 feet.

STOKE FERRY, near the Railway Station (? Dr. Baders). 1883.

Bored and communicated by MR. T. TILLEY.

Water rises to surface.

——	Thickness.	Depth.
	Feet.	Feet.
Sand [Drift] and water - - - -	25	25
[Lower Chalk] { Chalk, no water - -	13½	38½
[Lower Chalk] { Yellow marl - - -	3	41½
Gault (Blue clay) - - - - -	56	97½
[Lower Greensand, 17 feet.] { Dark green sand, no water -	2	99½
[Lower Greensand, 17 feet.] { Rock - - - -	2¼	101¾
[Lower Greensand, 17 feet.] { Green sand - - -	3¾	105½
[Lower Greensand, 17 feet.] { Rock - - - -	1½	107
[Lower Greensand, 17 feet.] { Sand - - - -	7½	114½

STOW BARDOLPH. Stow Hall and the Home Farm.

From MR. REID'S Notes.

Boulder Clay to sand (Lower Greensand), about 100 feet.

In another well, close to that at the Hall, and 114 feet deep, water was found at the depth of 27 feet.

WEST DEREHAM. Cottages near the church.

From MR. JUKES-BROWNE'S Notes.

Shaft 30 feet and bore 30 feet, through clay to sand [Lower Greensand] and water. The 60 feet must give nearly the full thickness of the Gault.

The following well-sections are in other parts of Norfolk, which have been already described in other Memoirs.

BLO' NORTON. The Hall. (Sheet 50, N.W.)

Communicated by MR. G. NORRIS, the owner.

Tube well into the Chalk at 54 feet. The tube driven in 4½ hours. Water rose to within 4 feet of the surface. ? 100 gallons a minute.

LONG STRATTON. Waston House. (Sheet 66, S.E.)

Boring, communicated by MR. T. W. N. CRAWFORD.

Gravel (Pebbles, sand, etc.), 34; Chalk and flints - 22 } 56 feet.

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NEEDHAM (S.W. of Harleston). A boring, 1889. (Sheet 50, N.E.)
Water-level, 78 feet down. Supply abundant.
From specimens communicated by MESSRS. ISLER & Co. (C. REID).

		Thickness.	Depth.
		Ft. In.	Ft. In.
Glacial Drift, 103 feet.	Yellow clay (weathered Boulder Clay)	2 6	2 6
	Chalky Boulder Clay	31 6	34 0
	Chalk, &c.	4 0	38 0
	Sand and gravel	21 0	59 0
	Chalky Boulder Clay	13 5	72 5
	Gravel and sand	10 5	82 10
	Bluish loam (? Lower Boulder Clay)	4 0	86 10
	Gravel (quartzose)	13 0	99 10
	Dark brown or blackish micaceous clay, with specks of vivianite (Lower Boulder Clay)	4 2	103 0
Pebbly Gravel, 34 feet.	Coarse loamy sand, with quartzite pebbles Earthy gravel, with flint, quartzite, &c. Clean gravel, with flint, quartzite, and vein-quartz	34 7	137 7
Norwich Crag, 61 feet.	Shelly gravel. *Mya, Tellina, Cardium edule, Mytilus, Pecten, Balanus*	5 0	142 7
	Gravelly sand	(?) 22 0	164 7
	Shell-bed. *Mya arenaria, Mytilus, Cardium, Purpura lapillus, Cyprina islandica, Mactra, Balanus crenatus*	1 5	166 0
	Greenish sand, with shells	28 0	194 0
	Green micaceous sandy silt	4 0	198 0
Upper Chalk.	Chalk with flints	112 0	310 0

An account sent by MESSRS. ISLER differs somewhat in details and makes the water-level only 69 feet down. It is thought better to give the above, which was carefully noted from specimens.

NORWICH. Marlingford. For Mr. E. B. Fletcher. 1884 (Sheet 66, N.E.)
Made and communicated by MESSRS. LEGRAND and SUTCLIFF.
Water-level, 45 feet down.

		Thickness.	Depth.
		Feet.	Feet.
[Drift.]	Loamy sand	4	4
	Clay and sand	7	11
	Light-coloured clay	2	13
	Light-blue clay	4	17
	Black peat	10	27
	Drift (Boulder Clay)	61	88
	Sand and clay	19	107
	Gravel	2	109
	Sand	1	110
	Gravel	4	114

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NORWICH. East Carleton. Lord Justice Lindsey. (Sheet 66, N.E.)

Made and communicated by MESSRS. LEGRAND and SUTCLIFFE.

Water-level, 14½ feet down.

		THICKNESS.	DEPTH.
		FEET.	FEET.
Dug well (the rest bored)		—	3
[Drift.]	Loamy clay	12	15
	Sand and gravel	10	25
Soft chalk and flints		55	80

NORWICH. Messrs. Caley's Mineral Water Works. 1890. (Sheet 66, N.E.)

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

Water-level, 88 feet down.

Originally only 307 feet deep (? yield 12 gallons a minute.) The supply doubled by deepening.

Old dug well (the rest bored), 101
Chalk and flints - - 311 } 412 feet.

WOOD NORTON. (Sheet 68, S.W.)

Communicated by MR. G. NORRIS, of Blo' Norton.

Different kinds of sand, 80 feet.

SUFFOLK.

As this Memoir is the last in which a description of any part of Suffolk has to be given, the following well-sections in that county, which have not been described in other Memoirs, are now given, although all of them are outside of our district.

COCKFIELD. Post Office rather more than half a mile N.W. of the Railway Station. 1890. (Sheet 50, S.W.)

REV. E. HILL, *Quart. Journ. Geol. Soc.*, vol. xlvii. p. 587.

About 270 feet above Ordnance datum.

Abandoned. No water found below the gravel.

		THICKNESS.	DEPTH.
		FEET.	FEET.
	Yellow clay (Brickearth ?)	8	8
	Red gravel with large flints	7	15
[Boulder Clay.]	Yellow clay with much small chalk	3	18
	Blue Boulder Clay with much chalk (well-rounded pebbles), masses of dark (? Kimeridge) clay full of *Ammonites*, often scratched. A chalk boulder 2 feet long	40	58
	Broken lumps of chalk and flints	5	63
	Blue clay with sub-rounded chalk fragments	20	83

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IPSWICH. Stoke. Messrs. Ransome and Rapier, Waterside Works. About 300 yards from the river. 1892. (Sheet 48, N.W.)

Made and communicated by MR. F. BENNETT.

Shaft 26 feet, with iron-cylinder inside; the rest bored (14½ inches diameter, internal ?); with tubes driven to 59 feet from the surface, their top being 14 feet from the surface.

Water stands from 5 to 6 feet down; this differs according to the tide. The water in the well has no connection with the water in the tube, as, after pumping a short time, all the water comes from the tube, the surface-supply not being enough for the required purpose.

—		Thickness.	Depth.
		Feet.	Feet.
Mixed gravel and sand		20	20
[Upper Chalk] 223½ feet.	Chalk and flints	6	26
	Chalk, with flints at 155, 201, 202, 224, 225, 236½, 237½, and 238 feet	212½	238½
	Rather soft chalk	5	243½

Analysis of the water, taken from the bore, after pumping for several hours. By MR. JAMES NAPIER:—

Total solid matters	99·5	Grains per gallon.
Chlorine	25·9	
Equal to Chloride of Sodium	42·68	
Nitrogen as Nitrates	·75	
Free Ammonia	·052	Parts per million.
Albumenoid Ammonia	·285	

Appearance, yellow. Hardness, 25°.

LEISTON. Messrs. R. Garrett and Sons Leiston Works. 1893. (Sheet 50, S.E.)

Communicated by MESSRS. GARRETT [with additional remarks from notes on samples by MR. C. REID, in these brackets].

A boring in the old shaft. 58 feet above Ordnance Datum. No adequate supply (January 1893).

—	Thickness.	Depth.
	Ft. In.	Ft. In.
Shaft [Drift and Red Crag ?]	—	35 10
Red shelly Crag [*Purpura lapillus*]	30 0	65 10
Pan of loam [hard loamy Crag]	0 6	66 4
Red shelly Crag	14 0	80 4
Red sand [Coarser shelly Crag]	3 6	83 10
Blue loam [bluish, sandy]	0 6	84 4
Blue sand [bluish-brown]	1 6	85 10
Blue loam [bluish, sandy]	2 0	87 10
Crag [blue, shelly. *Pectunculus glycimeris, Mactra, Cardium, Pecten, Nucula*]	8 0	95 10
Stiff loam [blue, with broken shells]	2 6	98 4
Crag [blue, with broken shells]	4 0	102 4
Stiff clay, with boulders [bluish, with ironstone-nodule]	0 6	102 10

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		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
[Red Crag.]	Blowing Crag [grey, with perfect shells. *Cyprina islandica, Tellina obliqua, Pecten opercularis, P. maximus, Trophon antiquus, Cardium grænlandicum, Natica, Buccinum, Purpura, Mactra*] -	6	6	109	4
	Stiff loam - - - -	2	0	111	4
	Crag [grey, with broken shells] -	3	0	114	4
	Blue loam [micaceous] - -	6	6	120	10
	Crag [coarse, grey, with broken *Turritella* and *Cyprina*] 3 inches of rock [shelly ironstone] at the base - - - -	3	9	124	7
	Blowing Crag [grey, with broken shells] - - - -	6	9	131	4
	Blowing sand [fine] - -	10	6	141	10
	Blowing Crag [grey, with broken shells. *Mya*] - - -	26	9	168	7
	Rock [two pitted polished phosphatic nodules, and a small septarian nodule ?] - -	1	1	169	8
[London Clay, 48½ feet.]	Clay [brown], with rock [septaria] at 183 ft. 4 in. to 184 ft. 6 in. and 7 in. at the base - -	22	3	191	11
	Clay (? brown, sandy, micaceous) [greenish-brown, mottled], with rock at 197 ft. 4 in. to 198 ft. -	26	1	218	0
[? Oldhaven Beds, over 26 feet.]	Loamy sand (? fine, grey, with flint pebbles) - - -	15	6	233	6
	Rock (sandstone) - - -	2	8	236	2
	Sand - - - -	8	0	244	2
[Reading Beds, over 53½ feet.]	Stiff clay - - - -	4	8	248	10
	Sand - - - -	2	4	251	2
	Clay - - - -	1	6	252	8
	Green loam - - -	3	6	256	2
	Mottled loam - - -	8	0	264	2
	Blue clay - - - -	4	6	268	8
	Dark green clay - - -	20	4	289	0
	Red clay - - - -	6	0	295	0
	Green clay - - -	1	9	296	9
	Flints - - - -	1	0	297	9
Chalk, hard, with flints at 319½, 332½, 352½, 380, 413 ft. 10 in., 436, 438, and 441 - -		189	3	487	0

Analysis of the water from the deep boring. By Mr. James Napier.

	Grains per Gallon.
Calcium carbonate - - - -	9·06
Magnesium carbonate - - -	1·05
Calcium sulphate - - - -	69·75
Magnesium sulphate - - -	24·04
,, nitrate - - - -	·65
,, chloride - - -	39·06
Sodium chloride - - - -	438·6
Alumina, oxide of iron, etc. - -	1·05
Silica - - - - -	·7
Organic matter and water of combination -	8·5
Total solid matters -	592·46

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The water is clearly therefore too salt to be used for boilers. It is difficult to account for the great quantity of sodium chloride.

The great thickness of Red Crag agrees with what has been proved by some other borings in Suffolk, which show that this formation thickens underground from its outcrop. It is very much more than was expected.

The apparent occurrence of Oldhaven Beds in considerable thickness is interesting.

The depth to the Chalk is greater than was reckoned on, and Mr. W. H. DALTON tells me that the plane of the Chalk-surface, which he had calculated, from data given by other borings, is nearly 70 feet higher. He thinks that the bend down is along a north and south line just west of Leiston, and that the base-line of the London Clay is a little eastward of Saxmundham.

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APPENDIX 2. TRIAL-BORINGS.

CAMBRIDGESHIRE.

BORINGS ALONG A LINE FROM CAMBRIDGE TO CROYLAND. 1836.

From a MS. book in the Geological Survey Office.

Nos. 1, 2, 3, 4, 4A, 4B are in Sheet 51 S.W., see Cambridge Memoir. The first two of the following are in Huntingdonshire, the others in Cambridgeshire.

——	THICKNESS.	DEPTH.
	FEET.	FEET.
5A. Thirty feet from the bank of the Twenty Foot Drain, 197 feet north of the Bridge; first fen in Warboys:—		
Black Peat	5	5
Brown Peat	3	8
Light Clay and Peat	4	12
Sand and Peat	4	16
Blue Sand	1	17
Gravel and Sand	2	19
Hard Gravel	to 6¼	25¼
5. Warboys Fen, 780 yards north of Plow Puttock Drove:—		
Black Peat	6	6
Brown Peat, with a deposit of wood	6	12
Dark Peat	6	18
Sand	2	20
Hard Gravel	to 7	27
6. Benwick parish, north side of Forty-foot Drove (Drain):—		
Black Peat	4	4
Loam and Peat	2	6
Pale Blue Clay, or Galt [Marine Clay]	11	17
Light Sand	5	22
Blue Clay	2	24
Sand and Blue Clay	1	25
Hard Gravel	4	29
7*. Benwick parish, south bank of R. Nene, 5 chains from Angle Bridge:—		
Black Loam [Peat]	3	3
Light Blue Galt [Marine Clay]	15	18
Dark Peat	2	20
Peat and decayed vegetable matter	3	22
Black Peat	7	30
Sand	1	31
Gravel	4	35

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—	Thickness.	Depth.
7. Side of R. Nene, Benwick parish :—	Feet.	Feet.
Black Loam [Peat Soil]	2	2
Brown Peat	7	9
Light Blue Galt [Marine Clay]	7	16
Peat, with decayed vegetable matter	10	26
Dark Sand	1	27
Hard Flinty Gravel	4	31

MARCH. In what was Hutchinson's Brickyard, in the fork between the Peterborough and the Wisbech branches of the railway. 1882.

Communicated by MR. A. A. LANGLEY, then Engineer to the Great Eastern Railway Company.

—	Thickness.	Depth.
	Feet.	Feet.
Rail-level to ground-level	—	10
Ballast	1½	11½
Silt	12½	24
Running silt	2	26
Hard Kimeridge Clay	45	71

MARCH. 15 trial-bores near the old Railway Station, for foundations, showed, according to MR. J. S. WINBOLT, blue Boulder Clay, at depths of from 6 to 10 feet. Another bore-hole, about 350 yards on the Spalding side of the new overline bridge (1884), north of the station and on the left of the railway, showed blue Boulder Clay at the depth of 7 feet, and 7 feet thick, when blue Kimeridge Clay was reached.

WISBECH. Site of proposed docks. 1883?

Communicated by MR. T. TILLEY.

—	Thickness.	Depth.
	Feet.	Feet.
Soil	1	1
[Alluvium] Silt and marl	5	6
[Alluvium] Quick silt, like water [? running sand]	14	20
[Alluvium] Black marl, to sand and water	2	22

The following borings, outside our district, were made some years after the publication of the Cambridge Memoir, and the account of them was not received until after the publication of that on the northern part of Sheet 51 (1891).

CAMBRIDGE. 10 borings, to settle for the foundations of Swimming-bath. Piece of ground eastward of St. John's Road and southward of Midsummer Common (up to roads on E. and S., not named on plan), near the river, between Great Bridge and Jesus' Weir. 1891? (Sheet 51 S.W.)

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Communicated by Mr. F. H. Anson.

The object was to find the depth to the Gault. That clay was bored into to the depth of a few inches in each case.

1. About 25 feet from the southern edge of plot, near middle. About 20½ feet above Ordnance Datum.

	Thickness.	Depth.
	Ft. In.	Ft. In.
Made ground, etc.	2 4	2 4
[Alluvium] Loam	5 2	7 6
[Alluvium] Alluvium	5 10	13 4
[Alluvium] Alluvium and sand	3 5	16 9
[Alluvium] „ „	3 7	20 4

2. About 8 feet from the southern edge of the plot, near middle. About 21 feet above Ordnance Datum.

	Thickness.	Depth.
	Ft. In.	Ft. In.
Made ground, etc.	2 4	2 4
[Alluvium] Loam	1 2	3 6
[Alluvium] Alluvium	4 10	8 4
[Alluvium] Peat	2 5	10 9
[Alluvium] Sand and peat	0 10	11 7
[River Drift] Sand	1 4	12 11
[River Drift] Gravel	4 9	17 8
[River Drift] Sand and gault	0 6	18 2

3. Near (25 feet from) the south-eastern corner of the plot. Over 19 feet above Ordnance Datum.
4. About 18 feet from the eastern edge of the plot, near middle. About 18¾ feet above Ordnance Datum.
5. A little S.W. of the middle of the plot. ? Over 19¾ feet above Ordnance Datum.
6. Near (35 feet from) the north-eastern corner of the plot. Nearly 20 feet above Ordnance Datum.

	3.		4.		5.		6.	
	Thick-ness.	Depth.	Thick-ness.	Depth.	Thick-ness.	Depth.	Thick-ness.	Depth.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Made ground, etc.	2 4	2 4	3 0	3 0	3 3	3 3	2 9	2 9
[Alluvium] Loam	1 5	3 9	1 7	4 7	3 6	6 9	4 9	7 6
[Alluvium] Alluvium	6 1	9 10	5 6	10 1	5 3	12 0	4 6	12 0
[Alluvium] Alluvium and Sand	3 0	12 10	0 11	11 0	2 4	14 4	1 6	13 6
[River Drift] Sand	3 2	16 0	2 11	13 11	—	—	0 10	14 4
[River Drift] Gravel	2 11	18 11	8 9	22 8	3 0	17 4	2 2	16 6
[River Drift] Gravel (3) or Sand (6) and Gault	3 9	22 8	—	—	—	—	0 8	17 2

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7. About 57 or 58 feet south-westward of 6. About 20½ feet above Ordnance Datum.

—	Thickness.	Depth.
	Ft. In.	Ft. In.
Made earth, etc.	2 6	2 6
[Alluvium] Loam	4 0	6 6
[Alluvium] Peat	5 10	12 4
[Alluvium] ?	1 0	13 4
[River Drift] Sand	2 4	15 8
[River Drift] Gravel	1 4	17 0
[River Drift] Running sand	0 10	17 10
[River Drift] Sand and Gault	0 8	18 6

8. In middle part of plot about 75 feet east of north from 5. About 20⅓ feet above Ordnance Datum.
9. About 24 feet southward of the north-western corner of the plot. Nearly 21½ feet above Ordnance Datum.
10. Nearly 5 feet from the middle of the western side of the plot. About 21½ feet above Ordnance Datum.

—	8.		9.		10.	
	Thick-ness.	Depth.	Thick-ness.	Depth.	Thick-ness.	Depth.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Made earth, etc.	3 0	3 0	2 9	2 9	3 11	3 11
[Alluvium] Loam	2 9	5 9	3 8	6 5	1 0	4 11
[Alluvium] Alluvium	8 10	14 7	11 1	17 6	13 5	18 4
[Alluvium] Alluvium and sand	2 11	17 6	4 0	21 6	2 10	21 2
[River Drift] Sand	—	—	1 8	23 2	—	—
[River Drift] Gravel	2 9	20 3	—	—	1 6 3 2	22 8 25 10
[River Drift] Gravel (8) or Sand (9) and Gault	0 7	20 10	1 7	24 9	—	—

NORFOLK.

Lynn. For proposed sewerage-works. 1882.
Communicated in Mr. J. Hall, Borough Surveyor.

—	Thickness.	Depth.
Blackfriars Road, in Plantation opposite Paxton Terrace.	Feet.	Feet.
[Made ground.] Soil	1½	1½
[Made ground.] Old rubbish	2½	4
[Alluvium] Bottom of old fleet [ditch]	4	8
[Alluvium] Blue clay	6	14
[Alluvium] White clay, to peat	6	20
Blackfriars Road, near the Railway Station.		
[Alluvium] Old clunch [? made ground]	4	4
[Alluvium] Blue clay	8	12
[Alluvium] Peat	5	17

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	Thickness.	Depth.
	Feet.	Feet.
Between St. John's Church and St. James' Road, in Churchyard.		
Old rubbish [made ground]	9	9
[Alluvium] Blue clay	3	12
[Alluvium] Peat	7	19
London Road. Framlingham's Almshouses.		
Old brick-rubbish	7	7
[Alluvium] Blue clay ?	5	12
[Alluvium] Peat ?	6	18
London Road. North Everard Street.		
[Alluvium] Blue clay to peat, 12 feet.		
Waterworks, Road near.		
[Alluvium] Loam	7	7
[Alluvium] Silt	3	10
Gaywood Road, near Salter's Road.		
[Alluvium] Silt	5	5
[Alluvium] Brown clay	2	7
[Alluvium] Peat ?	5	12
[Alluvium] Silt	3	15
Gaywood Road. Railway-crossing.		
[Alluvium] Shingle [? road-metal] and silt	3	3
[Alluvium] Brown clay mixed with silt	4	7
Littleport Bridge Cut.		
Brick-rubbish and shingle	6	6
[Alluvium] Black silt	4	10
[Alluvium] Peat	5	15
East Gates.		
[Alluvium] Black silt and shingle	15	15
[Alluvium] Blue clay	3	18
[Alluvium] Peat	2	20

Magdalen Bridge, "adjoining to the River Ouse."
C. B. Rose, *Geologist*, 1843, p. 75.

	Thickness.	Depth.
	Ft. In.	Ft. In.
Light soil and silt	5 8	5 8
Strong red clay, very stiff	2 4	8 0
Blue silt and clay	1 2	9 2
Moor [peat]	2 to 3 0	11 8 ?
Blue loam and clay	6 to 8 0	18 8 ?
Moor [peat]	2 to 3 0	20 2 ?
Black sand and gravel	2 4	22 6
Yellow sand and gravel	2 6	25 0

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NAR VALLEY DRAINAGE. Trial-borings. 1881 or 1882?
Communicated by MR. E. EASTON.

1. Site of the New Cut for the Nar, upstream end.
12·97 feet above Ordnance Datum.

		Thickness.	Depth.
		Feet.	Feet.
[Alluvium]	Top soil	5	5
	Soft blue clay	4	9
	Peat	3½	12½
	Soft blue clay	7	19½
To running silt and water.			

2. Site of the New Cut, on the upper side of the proposed dam.
13·57 feet above Ordnance Datum.

		Thickness.	Depth.
		Feet.	Feet.
[Alluvium, 23½ feet.]	Top soil	5	5
	Soft blue clay	4	9
	Peat	3½	12½
	Soft blue clay	7	19½
	Running silt, with water	4	23½
Gault, with grit, strong and dry [? Kimeridge Clay or Boulder Clay]		30	53½

The total is given as 54 feet.

3. Site of proposed Cut, on the lower side of the proposed dam.
9·97 feet above Ordnance Datum.

		Thickness.	Depth.
		Feet.	Feet.
[Alluvium]	Top soil	5	5
	Clay	4	9
	Peat	3½	12½
	Clay	7	19½
	Running silt and water	3½	23
To Gault, strong and dry [? Kimeridge Clay or Boulder Clay].			

4. Site of proposed Cut for the Nar near its junction with the old river, downstream end.
8·52 feet above Ordnance Datum.

		Thickness.	Depth.
		Feet.	Feet.
[Alluvium]	Top soil	2	2
	Soft blue clay	4	6
	Peat	3½	9½
	Soft blue clay	7	16½
	Silt and water	3½	20
To Gault, strong and dry [? Kimeridge Clay or Boulder Clay].			

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5. Near the Saddlebow Road.

9·97 feet above Ordnance Datum.

—		Thickness.	Depth.
		Feet.	Feet.
[Alluvium, 28 feet.]	Top soil	2	2
	Soft blue clay	11	13
	Peat	1	14
	Silt and clay	14	28
Gault [? Kimeridge Clay or Boulder Clay]		1	29

6. Near the Marshland Road. 7. Near the Ouse Bank.

10·46 and 14·29 feet above Ordnance Datum.

—		Thickness.		Depth.	
		(6.)	(7.)	(6.)	(7.)
		Feet.	Feet.	Feet.	Feet.
[Alluvium]	Top soil	5	5	5	5
	Soft blue clay	7	11	12	16
	Peat	3	4	15	20
	Silt and clay combined	17	23	32	43
To Gault [? Kimeridge Clay or Boulder Clay]		—	—	—	—

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* Before names of places means that they are outside the district.

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